BGP Communities:
Even more Worms in the Routing Can

ACM IMC 2018, Boston, MA, USA

Florian Streibelt[1] <fstreibelt@mpi-inf.mpg.de>,
Franziska Lichtblau[1], Robert Beverly[2], Cristel Pelsser[3],
Georgios Smaragdakis[4], Randy Bush[5], Anja Feldmann[1]

Nov 1, 2018

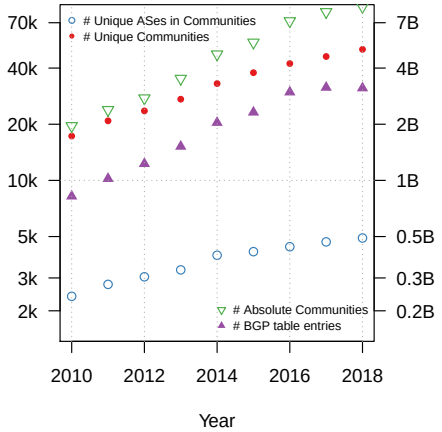
[1] Max Planck Institute for Informatics (MPII), [2] Naval Postgraduate School (NPS),
[3] University of Strasbourg, [4] TU Berlin (TUB), [5] Internet Initiative Japan (IIJ)

Introduction

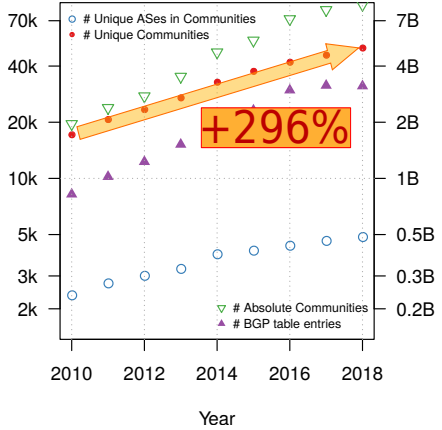
Contributions. . .

- We provide an analysis of BGP community propagation on the Internet
- We show that BGP communities (as used by operators to realize traffic management) can be used as attack vector
- We verify this via experiments in the lab as well as in the wild
- We provide some hints on the secure usage of BGP communities

BGP Community usage is increasing



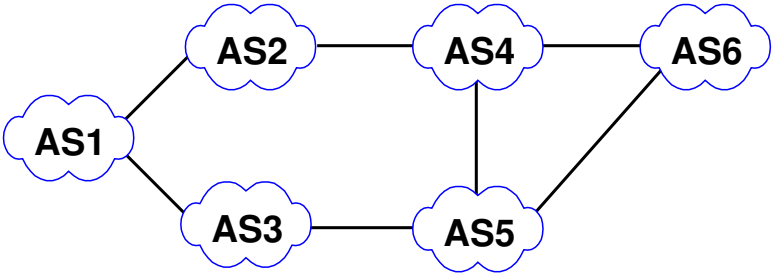
BGP Community usage is increasing



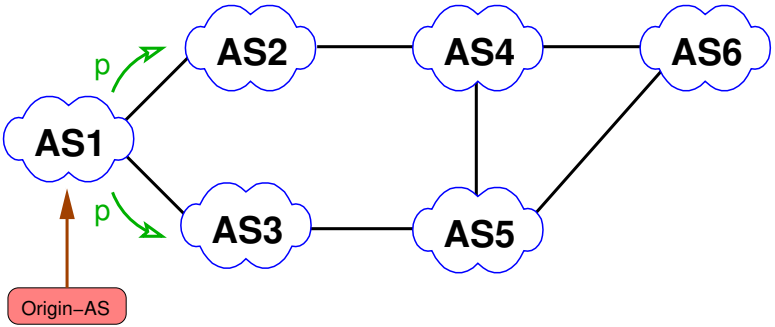
Increasing usage warrants a closer look.

BGP (Border Gateway Protocol)

BGP (Border Gateway Protocol)

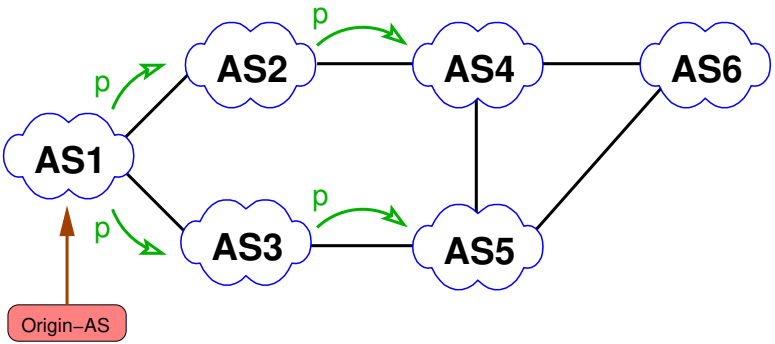


BGP (Border Gateway Protocol)



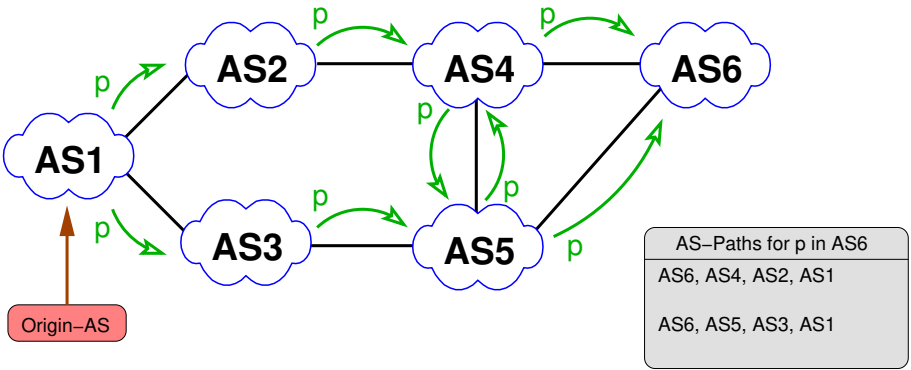
- AS1 announces prefix p

BGP (Border Gateway Protocol)



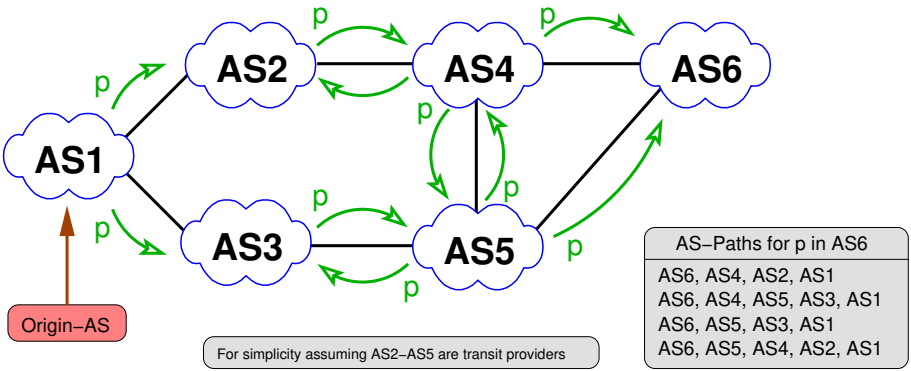
- AS1 announces prefix p, upstreams pickup p

BGP (Border Gateway Protocol)



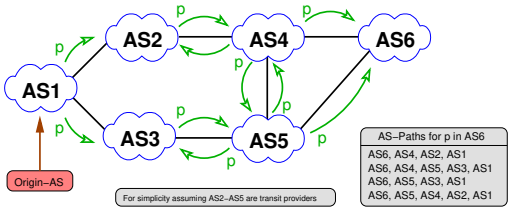
- AS1 announces prefix p, upstreams pickup p
- AS6 receives first anouncements for p

BGP (Border Gateway Protocol)



- AS1 announces prefix p, upstreams pickup p
- AS6 receives first anouncements for p
- eventually AS6 sees multiple available paths for p

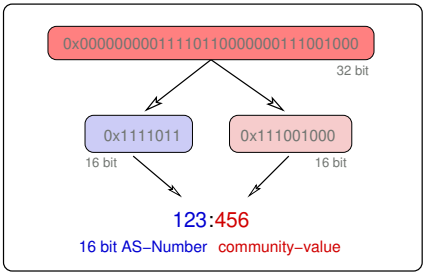
BGP (Border Gateway Protocol)



BGP

- BGP communicates reachability information
- Announcement messages also carry various attributes
- One of these attributes are BGP-Communities

BGP Communities



- RFC 1997: Optional Attribute in BGP message (32 bit)
- By convention written *ASN:VALUE*
- ASN can be both sender or intended 'recipient'
- Every network decides the semantics behind the values
- New standard: Large Communities (96 bit), not yet widely deployed

BGP Communities: Usage

Informational Communities (Passive Semantics)

- Location tagging
- RTT tagging

Action Communities (Active Semantics)

- Remote triggered blackholing
- Path prepending
- Local pref/MED
- Selective announcements

Used by operators to realize policies.

Without documentation, you can not tell if a community is active or passive!

BGP Communities As Attack Vector?

Given the **increasing popularity** of BGP communities
and the ability to **trigger actions** as well as **relay information**,
one question arises:

To which extend can BGP communities be leveraged for attacks?

Propagation behavior

- RFC 1997: Communities as a transitive optional attribute
- RFC 7454: Scrub own, forward foreign communities
- 14% of **transit** providers propagate received communities (2.2k of 15.5k)
- Ratio seems small, but AS graph is highly connected

Still many people do not expect communities to propagate that widely.

Potential (for) misuse

- Propagated communities might trigger actions multiple AS-hops away
- No way of knowing if intended or not, e.g., for traffic management
- But are there also unintended consequences?

Our assessment is that there is a high risk for attacks!

Observations

BGP Dataset

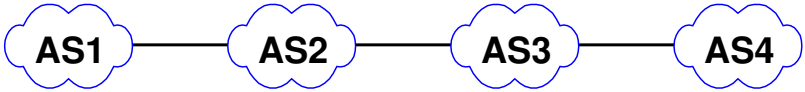
BGP updates and table dumps of April 2018 from publicly available BGP Collector Projects: RIPE RIS, Routeviews, Isolario, PCH.

BGP messages	38.98 bn
IPv4 prefixes	967,499
IPv6 prefixes	84,953
Collectors	194
AS peers	2,133
Communities	63,797

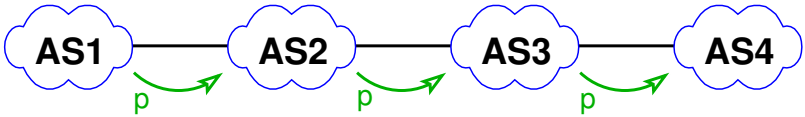
More than 75% of all BGP announcements have at least one BGP community set, 5,659 ASes are using communities.

BGP Communities propagation

BGP Communities propagation

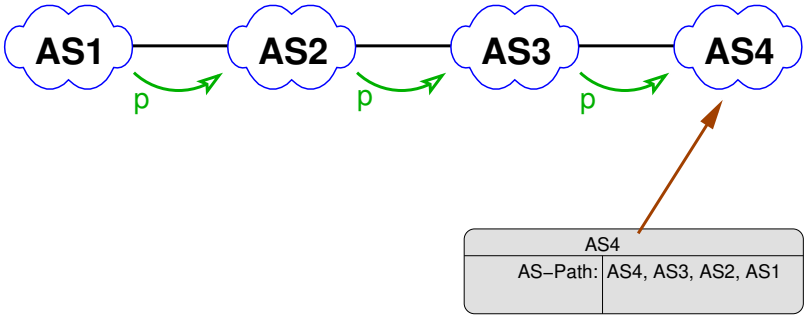


BGP Communities propagation



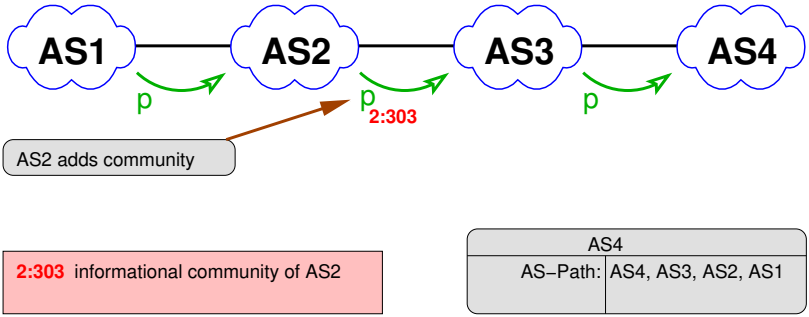
- AS1 announces prefix p

BGP Communities propagation



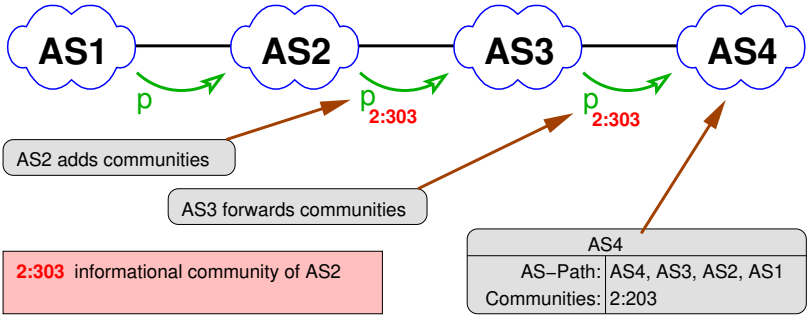
- AS1 announces prefix p, AS4 receives announcement

BGP Communities propagation



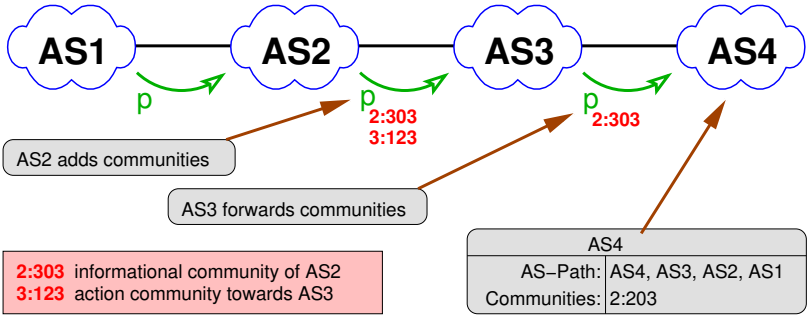
- AS1 announces prefix p, AS4 receives announcement
- Informational community *2:303* is added by AS2

BGP Communities propagation



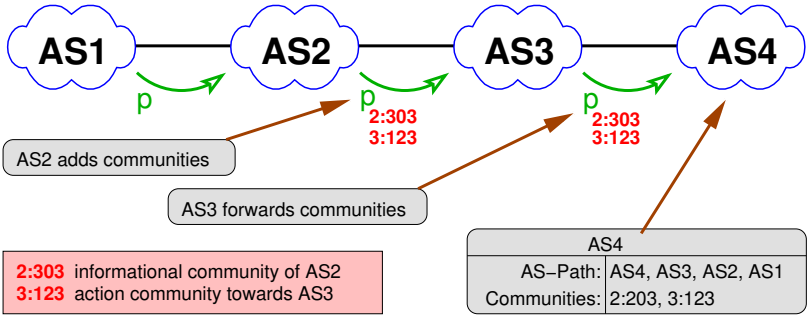
- AS1 announces prefix p, AS4 receives announcement
- Informational community *2:303* is added by AS2

BGP Communities propagation



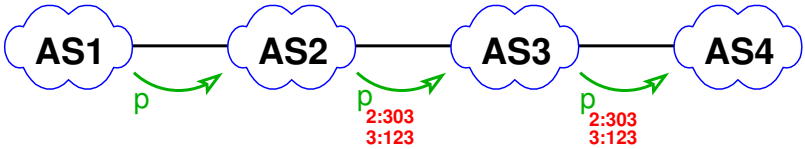
- AS1 announces prefix p, AS4 receives announcement
- Informational community *2:303* is added by AS2
- AS2 also adds action community *3:123* for AS3

BGP Communities propagation



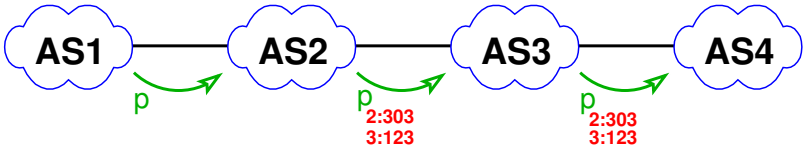
- AS1 announces prefix p, AS4 receives announcement
- Informational community *2:303* is added by AS2
- AS2 also adds action community *3:123* for AS3
- Both communities are forwarded by AS3 to AS4

BGP Communities propagation



AS4	
AS–Path:	AS4, AS3, AS2, AS1
Communities:	2:203, 3:123

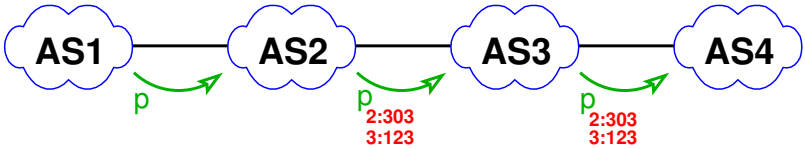
BGP Communities propagation



AS4	
AS–Path:	AS4, AS3, AS2, AS1
Communities:	2:203, 3:123

- We can only infer which AS added a specific community

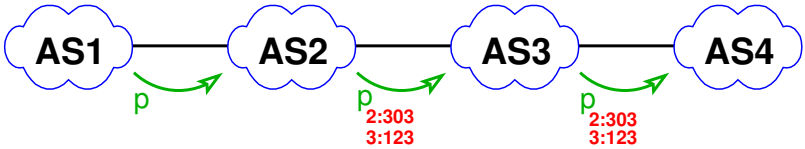
BGP Communities propagation



AS4	
AS–Path:	AS4, AS3, AS2, AS1
Communities:	2:203, 3:123

- We can only infer which AS added a specific community
- We assume that a community *n:value* was added by AS n

BGP Communities propagation



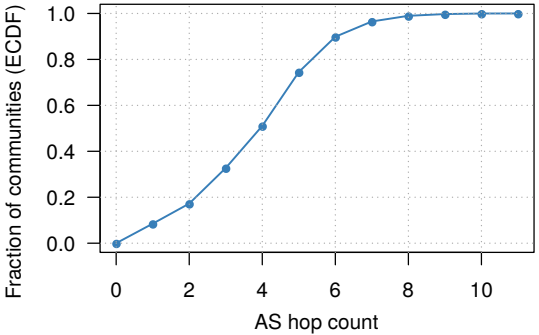
inferred travel–distance is a lower bound!

2:303	traversed at least two AS–links
3:123	traversed at least one AS–link

AS4	
AS–Path:	AS4, AS3, AS2, AS1
Communities:	2:203, 3:123

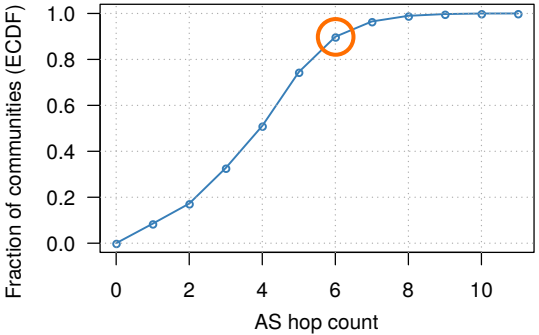
- We can only infer which AS added a specific community
- We assume that a community *n:value* was added by AS n
- This gives a **lower bound** for the 'travel distance'
- In above example we calculate AS-hop-count 1 for *3:123*

BGP Community Propagation Observations



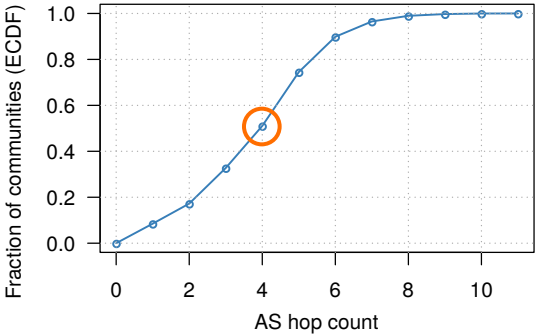
- 10% of communities have a AS hop count of more than six
- More than 50% of communities traverse more than four ASes
- Longest community propagation observed: 11 AS hops

BGP Community Propagation Observations



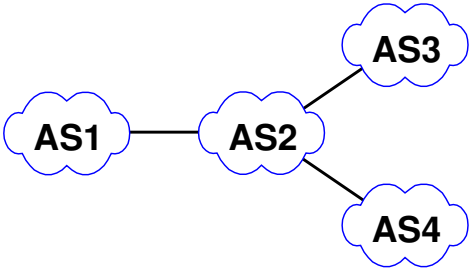
- 10% of communities have a AS hop count of more than six
- More than 50% of communities traverse more than four ASes
- Longest community propagation observed: 11 AS hops

BGP Community Propagation Observations

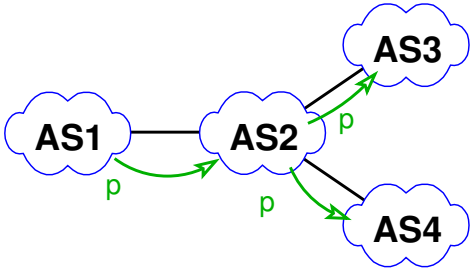


- 10% of communities have a AS hop count of more than six
- More than 50% of communities traverse more than four ASes
- Longest community propagation observed: 11 AS hops

BGP Community Propagation Behavior

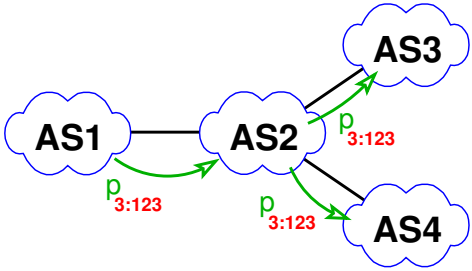


BGP Community Propagation Behavior



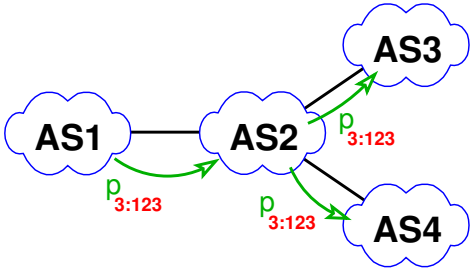
- AS1 announces prefix p

BGP Community Propagation Behavior



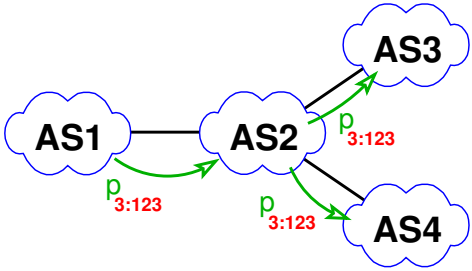
- AS1 announces prefix p, tagged with 3:123

BGP Community Propagation Behavior



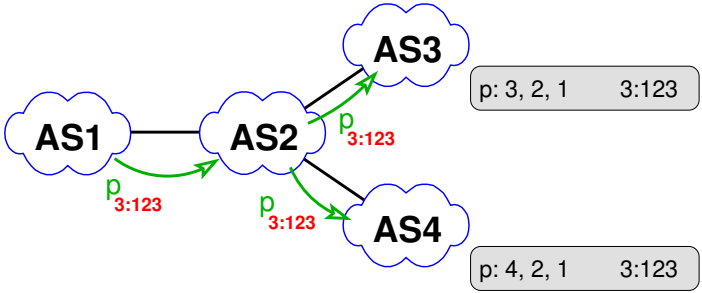
- AS1 announces prefix p, tagged with 3:123
- Community is intended for signaling towards AS3

BGP Community Propagation Behavior



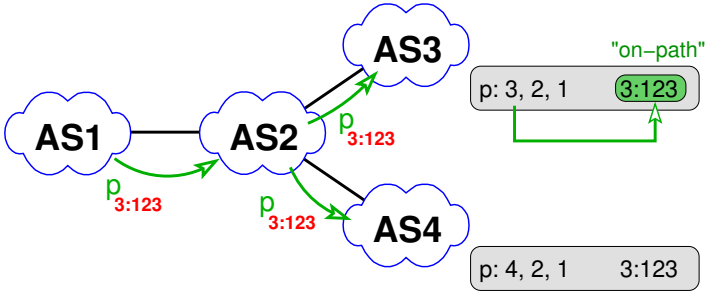
- AS1 announces prefix p, tagged with 3:123
- Community is intended for signaling towards AS3
- AS4 also receives this announcement

BGP Community Propagation Behavior



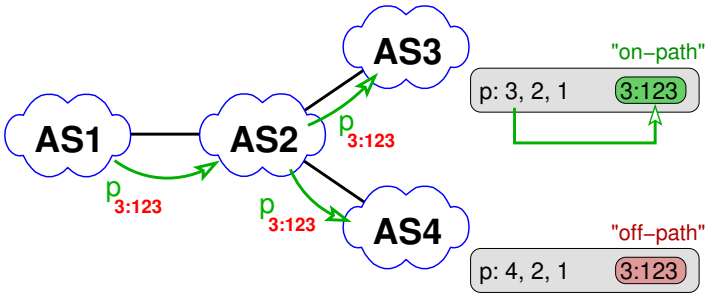
- AS1 announces prefix p, tagged with 3:123
- Community is intended for signaling towards AS3
- AS4 also receives this announcement

BGP Community Propagation Behavior



- AS1 announces prefix p, tagged with 3:123
- Community is intended for signaling towards AS3
- AS4 also receives this announcement

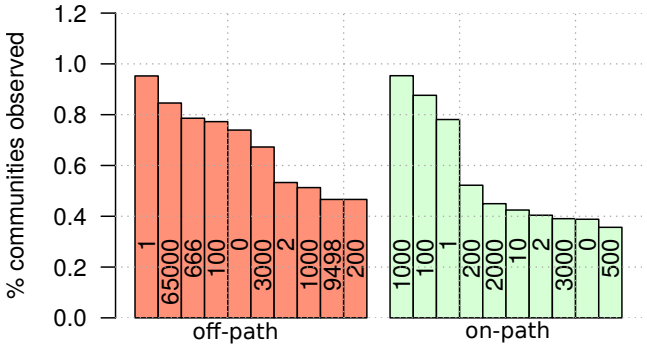
BGP Community Propagation Behavior



- AS1 announces prefix p, tagged with 3:123
- Community is intended for signaling towards AS3
- AS4 also receives this announcement

Off-path: ASN from community is not on the observed AS-path at AS4.

On-path versus off-path



- Blackholing communities (e.g., :666) 'leaking' off path
- But AS implementing RTBH `SHOULD` add `NO_ADVERTISE` or `NO_EXPORT` (RFC7999)

Suggests ASes not implementing RTBH do not filter.

Experiments

Experimental setup

- Experiments conducted in a lab environment[1]
- Validated on the Internet

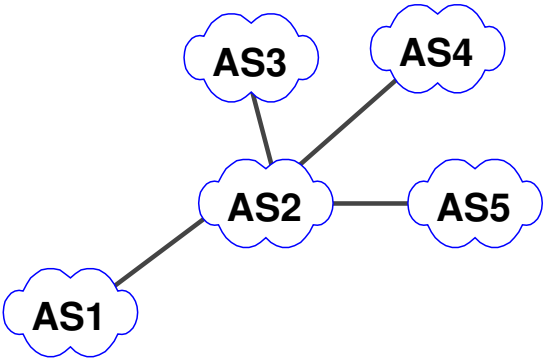
Scenarios

- Remote Triggered Blackholing (RTBH)
- Traffic redirection attack

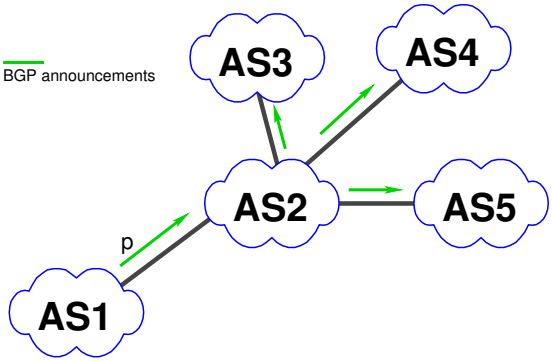
...more in the paper.

[1] Configurations available at: `https://www.cmand.org/caas/`

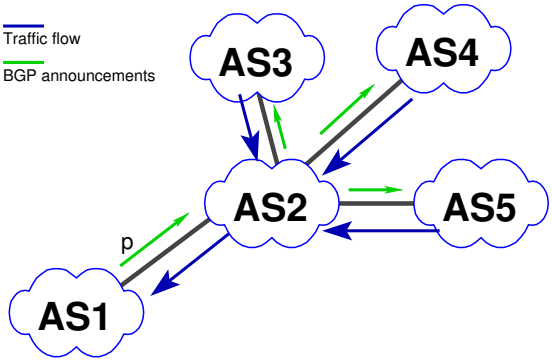
RTBH: How It Works



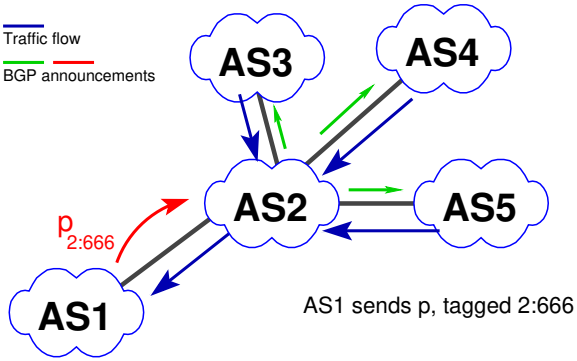
RTBH: How It Works



RTBH: How It Works

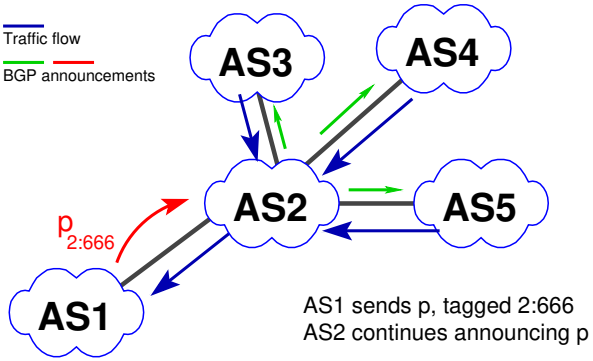


RTBH: How It Works



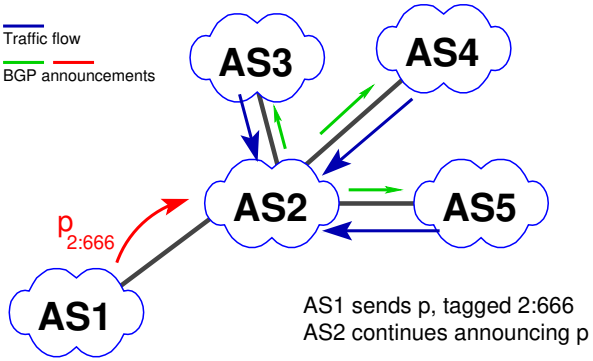
- AS announces BH-prefix to upstream

RTBH: How It Works



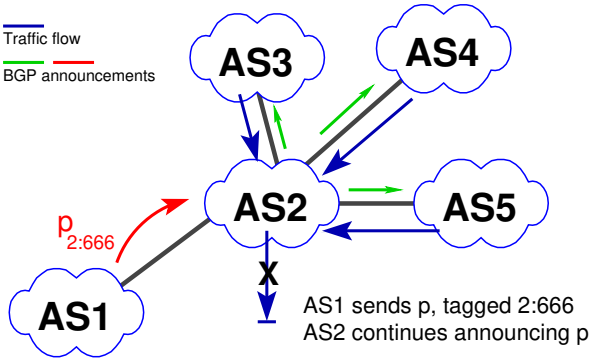
- AS announces BH-prefix to upstream

RTBH: How It Works



- AS announces BH-prefix to upstream

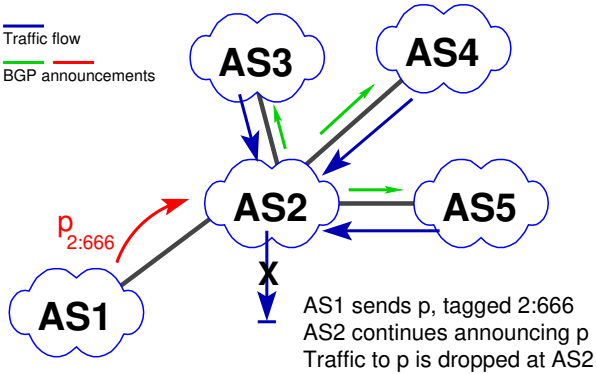
RTBH: How It Works



- AS announces BH-prefix to upstream

→ Provider blackholes prefix

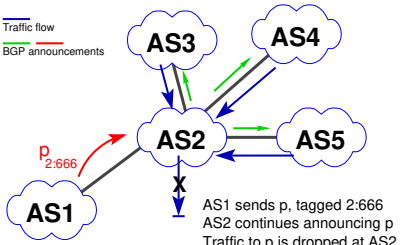
RTBH: How It Works



- AS announces BH-prefix to upstream

→ Provider blackholes prefix

RTBH: How It Works



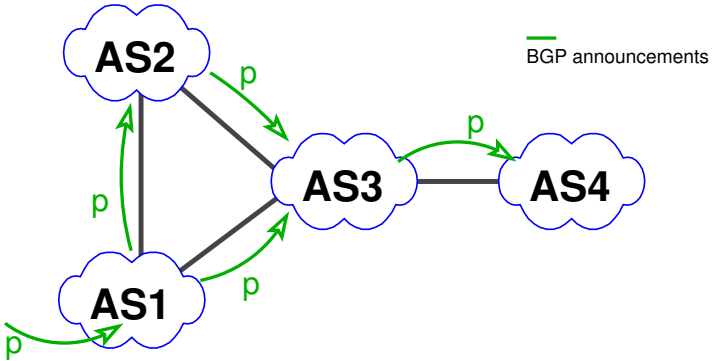
- AS announces BH-prefix to upstream

→ Provider blackholes prefix

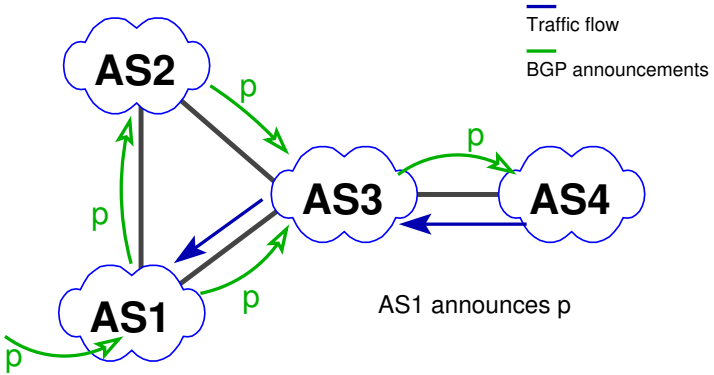
Safeguards

- Provider should check customer prefix before accepting RTBH
- Customer may only blackhole own prefixes
- Different policies for Customers/Peers
- On receiving RTBH, add `NO_ADVERTISE` or `NO_EXPORT` (RFC7999)

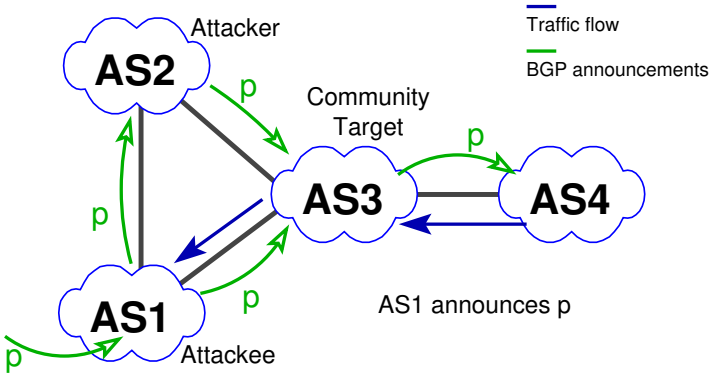
RTBH: How It Should Not Work



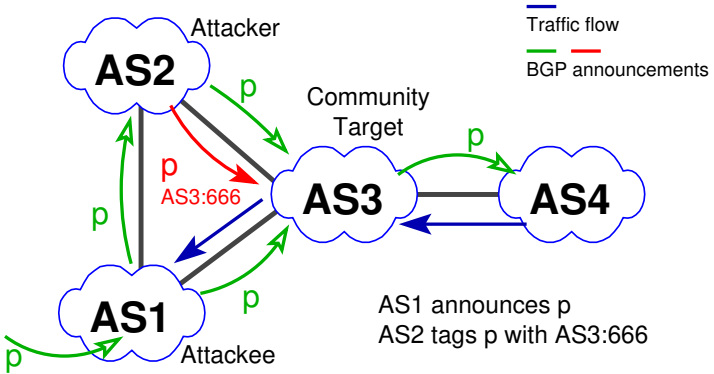
RTBH: How It Should Not Work



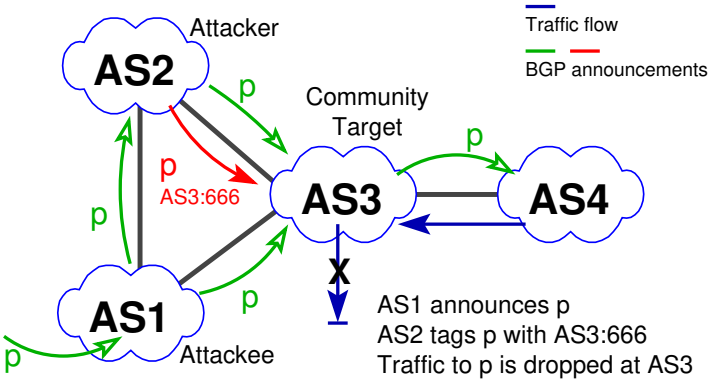
RTBH: How It Should Not Work



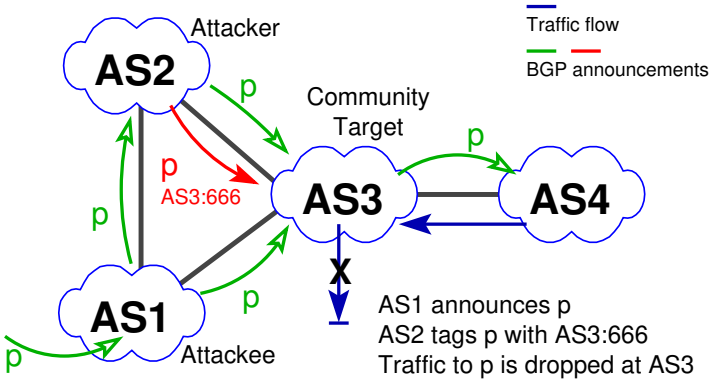
RTBH: How It Should Not Work



RTBH: How It Should Not Work

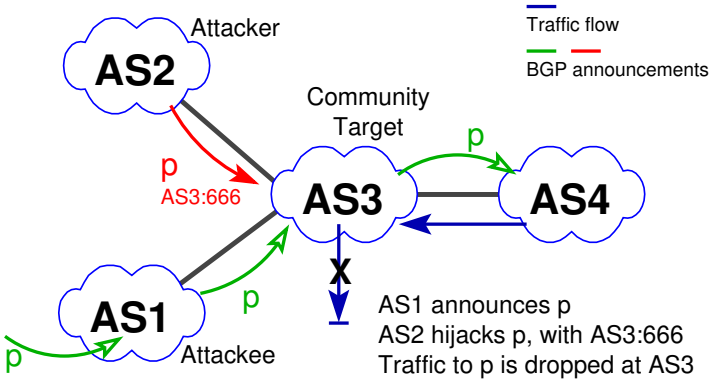


RTBH: How It Should Not Work



- AS on 'backup' path adds RTBH-community
- Provider blackholes prefix
- Not only traffic traversing AS2 is dropped

RTBH: How It Should Not Work (with hijack)



- Hijacker announces RTBH
- Prefix filters circumvented due to misconfiguration
- Provider blackholes prefix

RTBH: Attack Confirmed

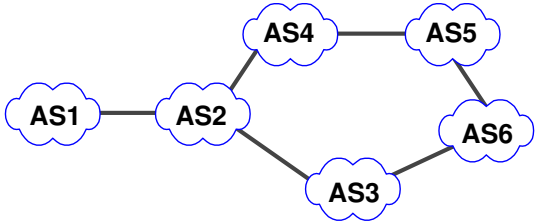
Attack confirmed to work on the Internet, works multi hop and is hard to spot

Triggering RTBH is possible for attackers because, e.g.,:

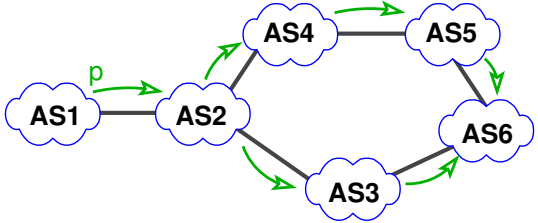
- BH prefix is more specific, accepted via exception
- Providers check BH community before prefix filters[2]
- `NO_ADVERTISE` or `NO_EXPORT` often is ignored / not set
- Problem: No validation for origin of community

[2] we found configuration guides with that bug

Traffic Redirection Attack

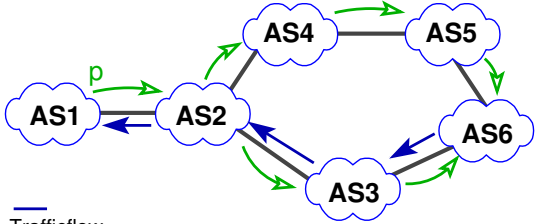


Traffic Redirection Attack



BGP−Announcements

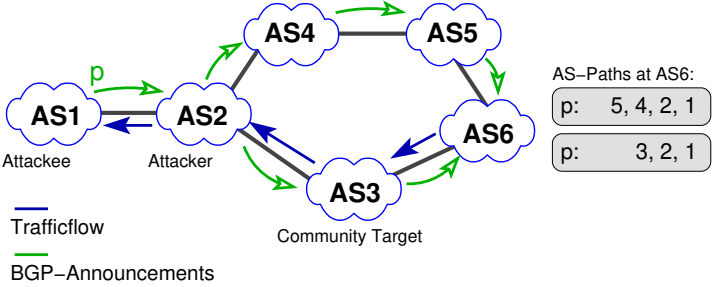
Traffic Redirection Attack



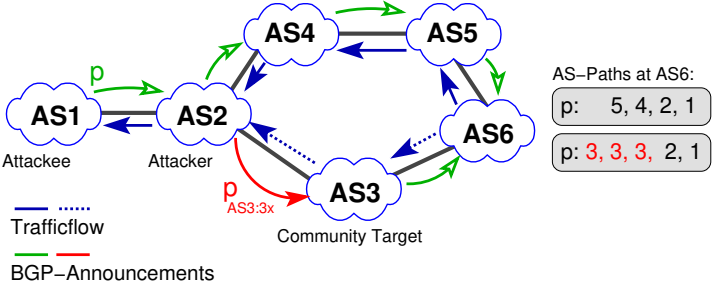
AS−Paths at AS6:

p:	5, 4, 2, 1
p:	3, 2, 1

Traffic Redirection Attack

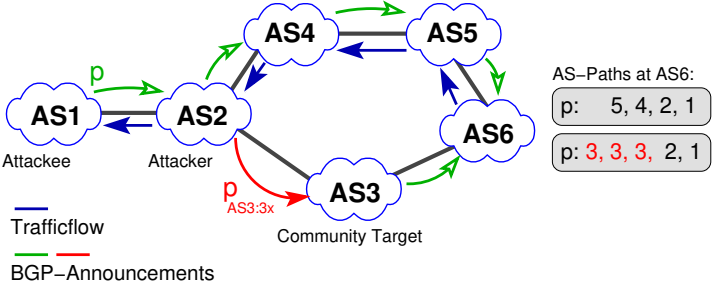


Traffic Redirection Attack



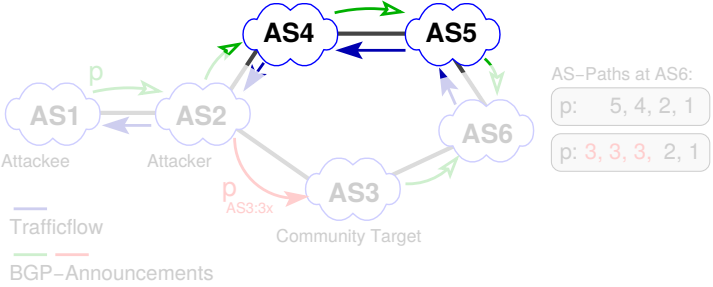
- Attacker AS2 uses community to add path-prepending in AS3

Traffic Redirection Attack



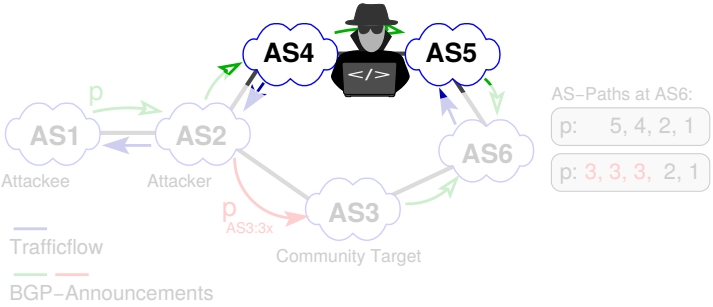
- Attacker AS2 uses community to add path-prepending in AS3
- AS6 routes traffic towards prefix p via AS5, AS4

Traffic Redirection Attack



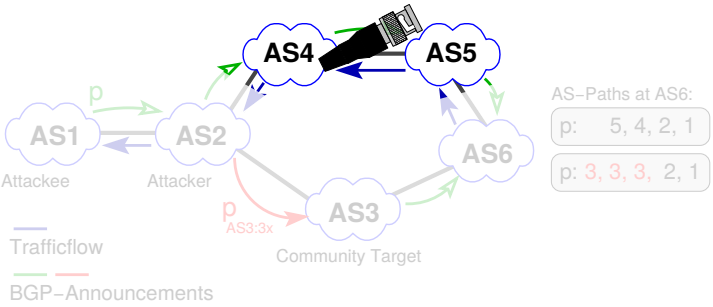
- Attacker AS2 uses community to add path-prepending in AS3
- AS6 routes traffic towards prefix p via AS5, AS4

Traffic Redirection Attack



- Attacker AS2 uses community to add path-prepending in AS3
- AS6 routes traffic towards prefix p via AS5, AS4
  - Network tap?

Traffic Redirection Attack



- Attacker AS2 uses community to add path-prepending in AS3
- AS6 routes traffic towards prefix p via AS5, AS4
  - Network tap?
  - Slow/Congested link?
  - ...

Communities Confirmed In Attacks

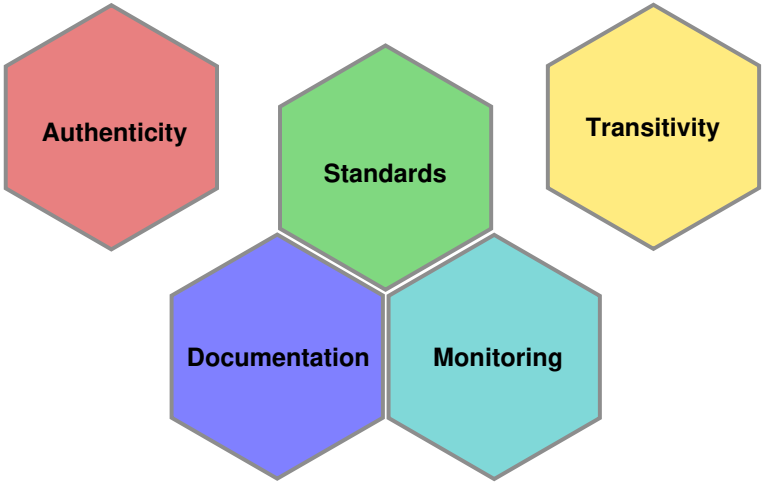
Attack on 10 July 2018

"For about 30 minutes, these hijack prefixes weren't propagated very far. Then they were announced again at 23:37:47 UTC for about 15 minutes but to a larger set of peers — 48 peers instead of 3 peers in the previous hour.
It appears a change of BGP communities from 24218:1120 to 24218:1 increased the route propagation."

Source: `https://dyn.com/blog/bgp-dns-hijacks-target-payment-systems/`

Discussion

Discussion


Authenticity
Standards
Transitivity
Documentation
Monitoring

Discussion: Authenticity

- Communities can be modified, added, removed by every AS
- No attribution is possible
- No cryptographic protection (RPKI does not help)
- Still operators rely on their ‘correctness’
- Large communities partially improve the situation

How can we achieve authenticity, or at least attribution?

Discussion: Transitivity

- Communities can help in debugging
- Easy, low overhead communication channel
- Widely in use, but often only 1-2 hops
- But: High risk of being abused!

Are fully transitive communities still worth the clear risk?

Discussion: Monitoring

- There is no global state in BGP
- Route collectors only see the 'end-result'
- Inferring modifications between origin-AS and collector: almost impossible
- The meaning of a particular community can not be known
- No universal way for attribution of changes

Monitoring communities to detect abuse is extremely difficult.

Discussion: Standards

- There are limited standardized communities
- Many AS do not implement these
- Is the lack of standardized communities a problem?
- Are standards doing harm, by helping attackers?
- Security by obscurity never works

Standardization is necessary.

Discussion: Documentation

- Communities are individually defined by the ASes
- Documentation, if available, is scattered over whois, websites, customer-portals, ...
- Not in machine-readable format, often natural language
- Automated parsing can work for limited scope/fixed applications
- Parsing for general purpose applications is not feasible

Documentation is limited and fragmented.

Summary

Communities Shortcomings

- Semantics loosely defined, no authenticity
- Secure usage requires good **operational knowledge** and **diligence**
- Attacks are possible and indeed already happening

Summary

Communities Shortcomings

- Semantics loosely defined, no authenticity
- Secure usage requires good **operational knowledge** and **diligence**
- Attacks are possible and indeed already happening

Future Work

- Attack detection
- Attribution
- Distributed realtime monitoring?
- Protocol improvements for BGP?

Appendix

Recommendations for Operators

- AS should filter incoming Informational Communities carrying their ASN
- Agreements with Downstreams might be needed, e.g., to filter Action Communities
- Publicly documenting Communities used is key to enable other AS to filter
- Monitoring/Logging received communities for tracking abuse
- Providing public looking glasses, showing communties, helps debugging