Communication Networks

Spring 2024

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nsg.ee.ethz.ch

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D-ITET

Materials inspired from Scott Shenker & Jennifer Rexford

Border Gateway Protocol

policies and more

BGP Policies

Follow the Money

Protocol

How does it work?

3 Problems

security, performance, …

BGP suffers from many rampant problems

Problems	Reachability
	Security
	Convergence
	Performance
	Anomalies
	Relevance

Problems

Reachability

Security

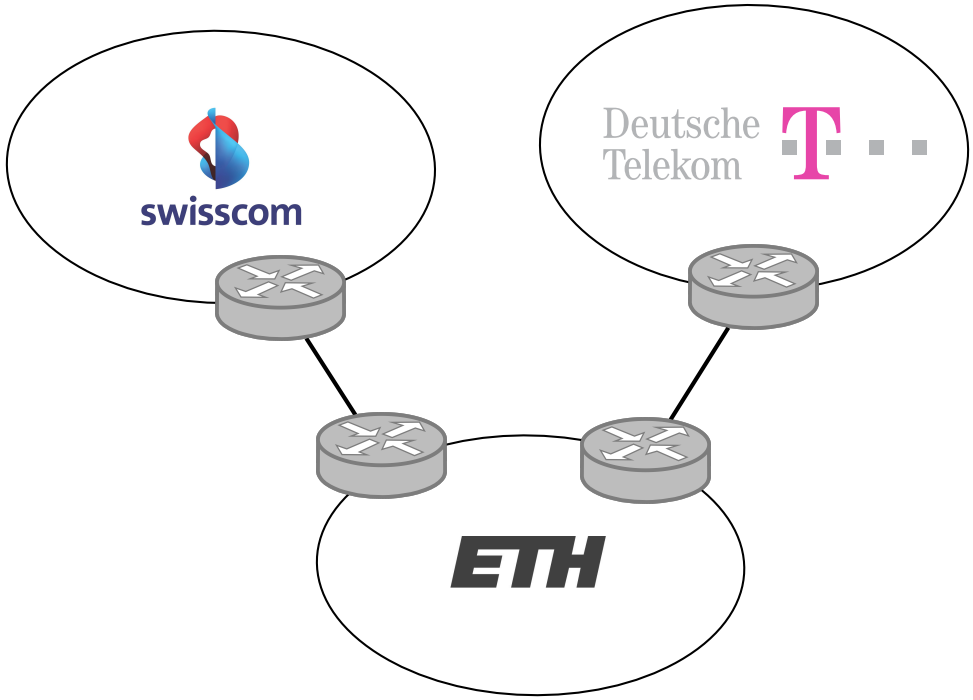
Convergence

Performance

Anomalies

Relevance

Unlike normal routing, policy routing does not guarantee reachability even if the graph is connected



Because of policies,

Swisscom cannot reach DT

even if the graph is connected

Problems

Reachability

Security

Convergence

Performance

Anomalies

Relevance

Many security considerations are absent from the BGP specification

ASes can advertise any prefixes

even if they don't own them!

ASes can arbitrarily modify route content

e.g., change the content of the AS-PATH

ASes can forward traffic along different paths

than the advertised one

BGP (lack of) security

#1 BGP does not validate the origin of advertisements

#2 BGP does not validate the content of advertisements

BGP (lack of) security

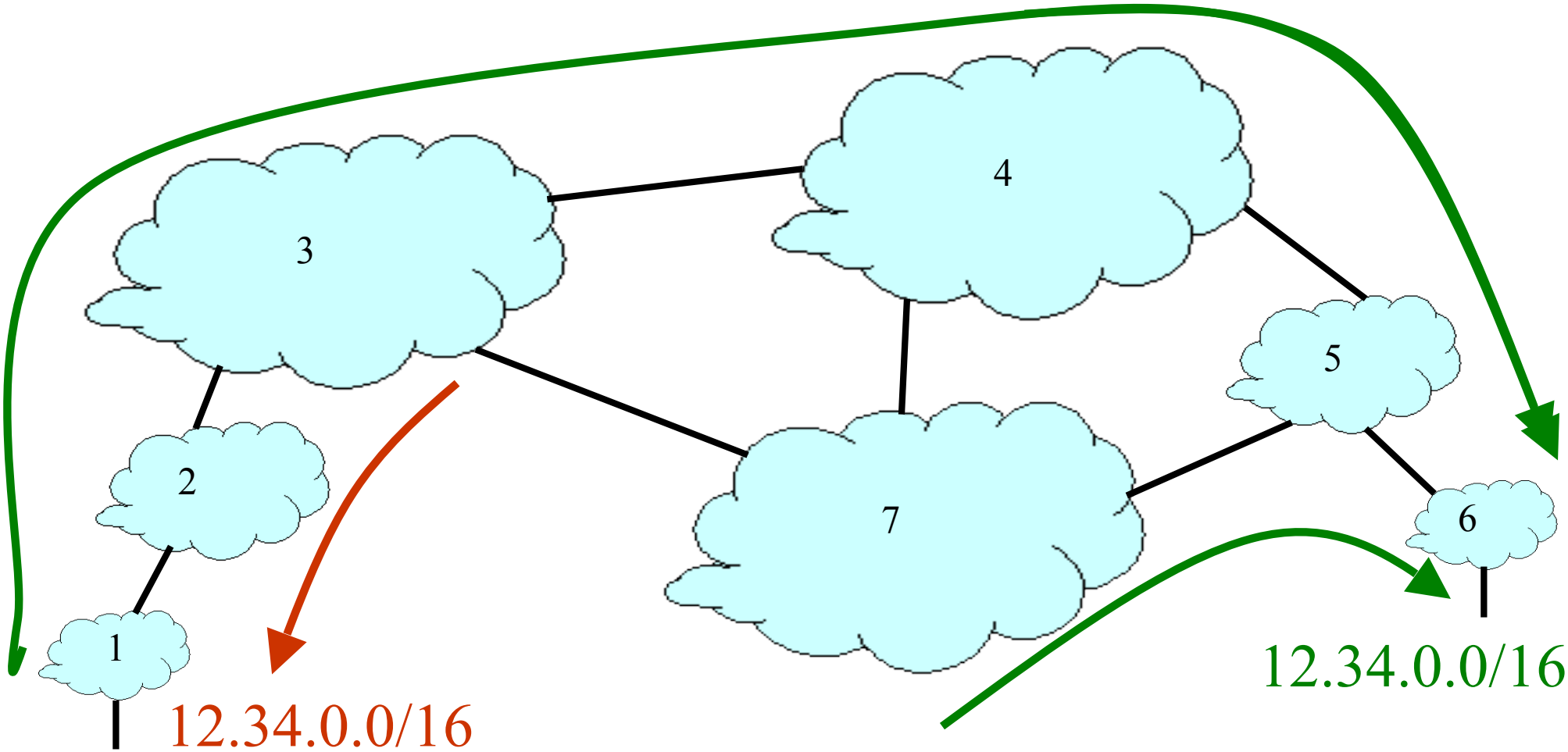
#1 BGP does not validate the origin of advertisements

#2 BGP does not validate the content of advertisements

IP Address Ownership and Hijacking

- IP address block assignment
  - Regional Internet Registries (ARIN, RIPE, APNIC)
  - Internet Service Providers
- Proper origination of a prefix into BGP
  - By the AS who owns the prefix
  - … or, by its upstream provider(s) in its behalf
- However, what's to stop someone else?
  - Prefix hijacking: another AS originates the prefix
  - BGP does not verify that the AS is authorized
  - Registries of prefix ownership are inaccurate

Prefix Hijacking

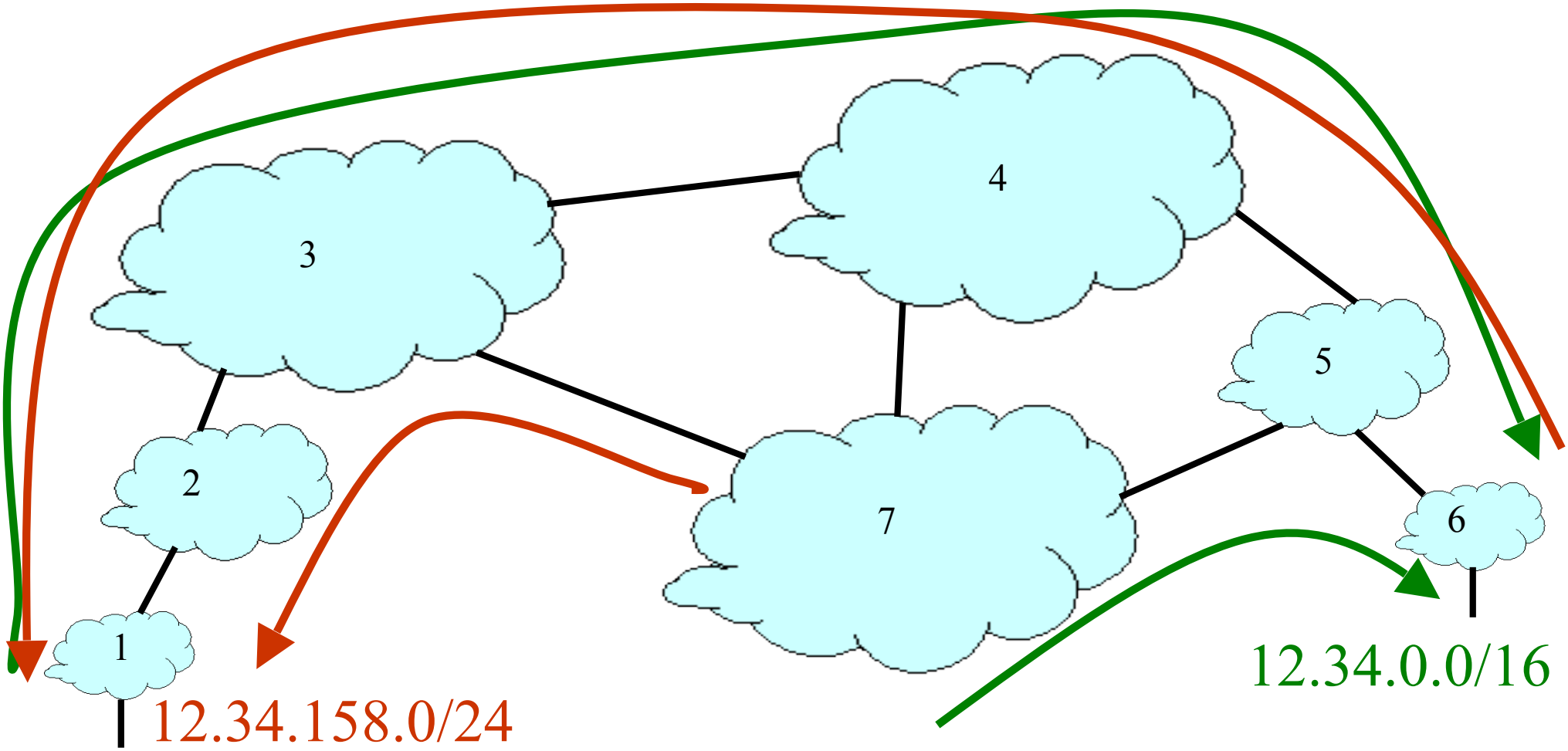


- Blackhole: data traffic is discarded
- Snooping: data traffic is inspected, then redirected
- Impersonation: traffic sent to bogus destinations

Hijacking is Hard to Debug

- The victim AS doesn't see the problem
  - Picks its own route, might not learn the bogus route
- May not cause loss of connectivity
  - Snooping, with minor performance degradation
- Or, loss of connectivity is isolated
  - E.g., only for sources in parts of the Internet
- Diagnosing prefix hijacking
  - Analyzing updates from many vantage points
  - Launching traceroute from many vantage points

Sub-Prefix Hijacking



- Originating a more-specific prefix
  - Every AS picks the bogus route for that prefix
  - Traffic follows the longest matching prefix

How to Hijack a Prefix

- The hijacking AS has
  - Router with BGP session(s)
  - Configured to originate the prefix
- Getting access to the router
  - Network operator makes configuration mistake
  - Disgruntled operator launches an attack
  - Outsider breaks in to the router and reconfigures
- Getting other ASes to believe bogus route
  - Neighbor ASes do not discard the bogus route
  - E.g., not doing protective filtering

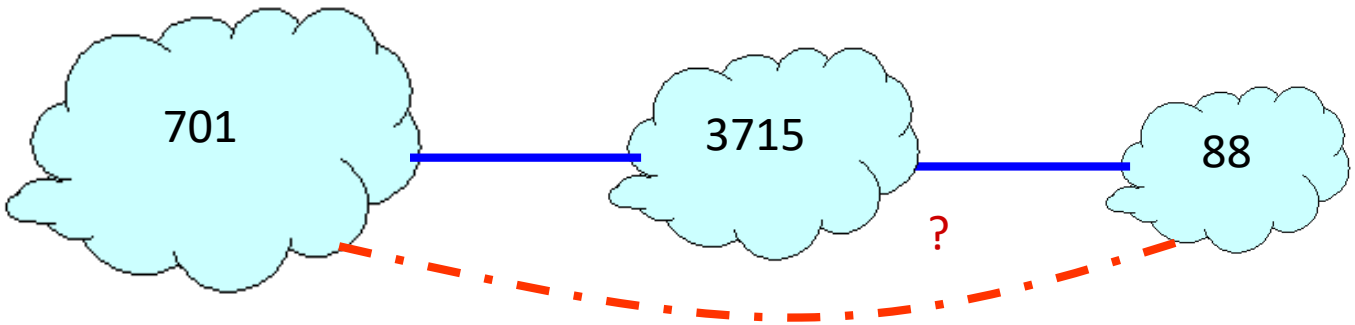
BGP (lack of) security

#1 BGP does not validate the origin of advertisements

#2 BGP does not validate the content of advertisements

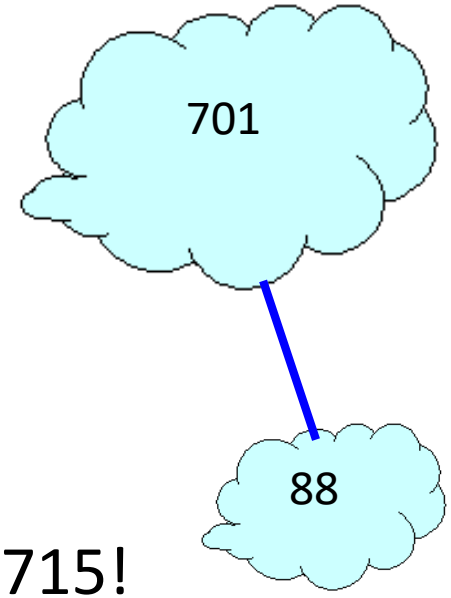
Bogus AS Paths

- Remove ASes from the AS path
  - E.g., turn “701 3715 88” into “701 88”
- Motivations
  - Attract sources that normally try to avoid AS 3715
  - Help AS 88 look like it is closer to the Internet’s core
- Who can tell that this AS path is a lie?
  - Maybe AS 88 *does* connect to AS 701 directly



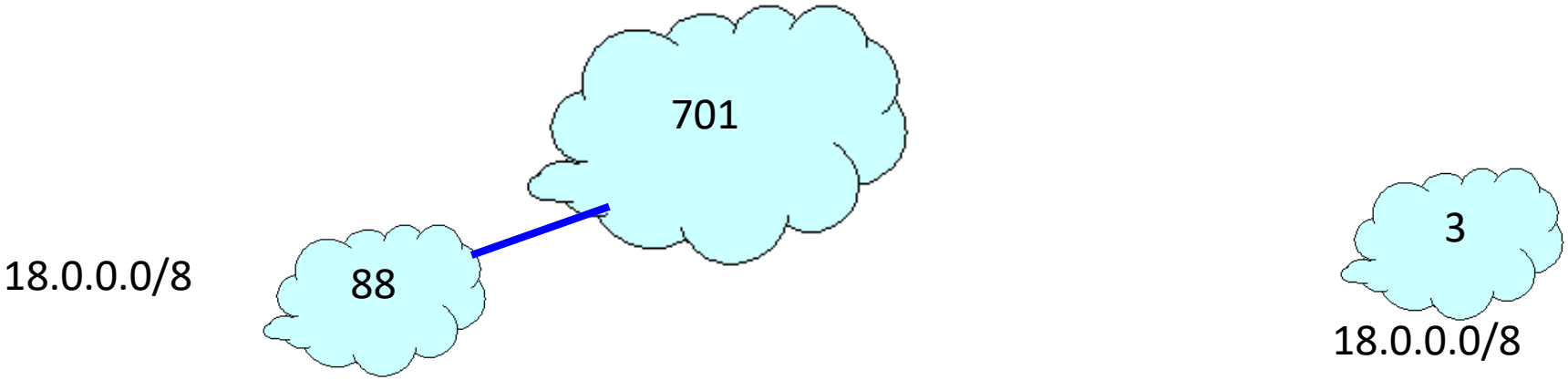
Bogus AS Paths

- Add ASes to the path
  - E.g., turn “701 88” into “701 3715 88”
- Motivations
  - Trigger loop detection in AS 3715
    - Denial-of-service attack on AS 3715
    - Or, blocking unwanted traffic coming from AS 3715!
  - Make your AS look like is has richer connectivity
- Who can tell the AS path is a lie?
  - AS 3715 could, if it could see the route
  - AS 88 could, but would it really care?



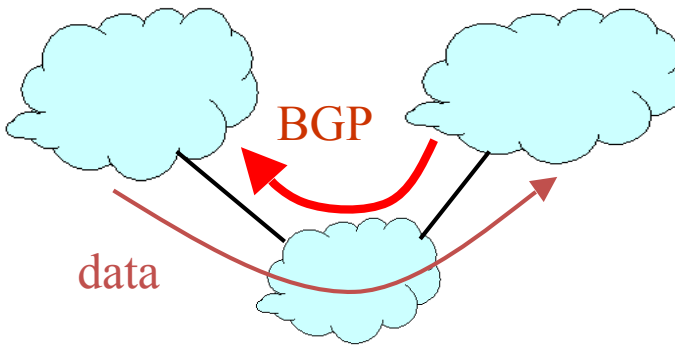
Bogus AS Paths

- Adds AS hop(s) at the end of the path
  - E.g., turns “701 88” into “701 88 3”
- Motivations
  - Evade detection for a bogus route
  - E.g., by adding the legitimate AS to the end
- Hard to tell that the AS path is bogus…
  - Even if other ASes filter based on prefix ownership



Invalid Paths

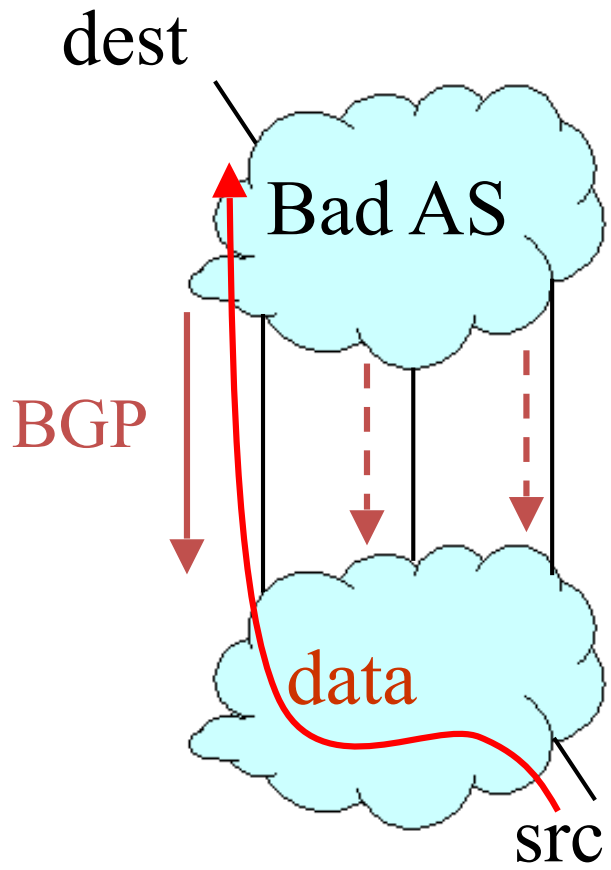
- AS exports a route it shouldn't
  - AS path is a valid sequence, but violated policy
- Example: customer misconfiguration
  - Exports routes from one provider to another
- Interacts with provider policy
  - Provider prefers customer routes
  - Directing all traffic through customer



- Main defense
  - Filtering routes based on prefixes and AS path

Missing/Inconsistent Routes

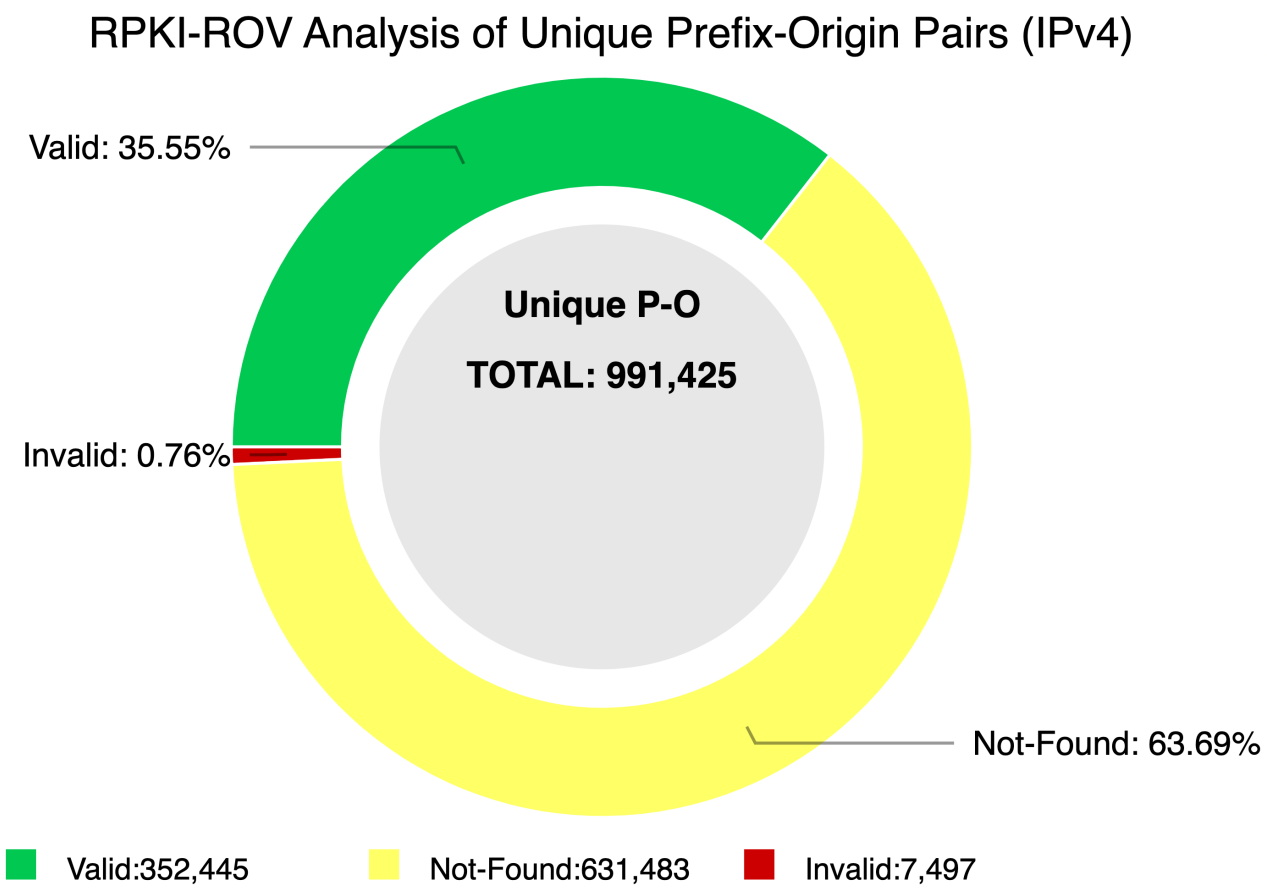
- Peers require consistent export
  - Prefix advertised at all peering points
  - Prefix advertised with same AS path length
- Reasons for violating the policy
  - Trick neighbor into "cold potato"
  - Configuration mistake
- Main defense
  - Analyzing BGP updates, or traffic,
  - … for signs of inconsistency



Proposed Enhancements to BGP

BGP Security Today

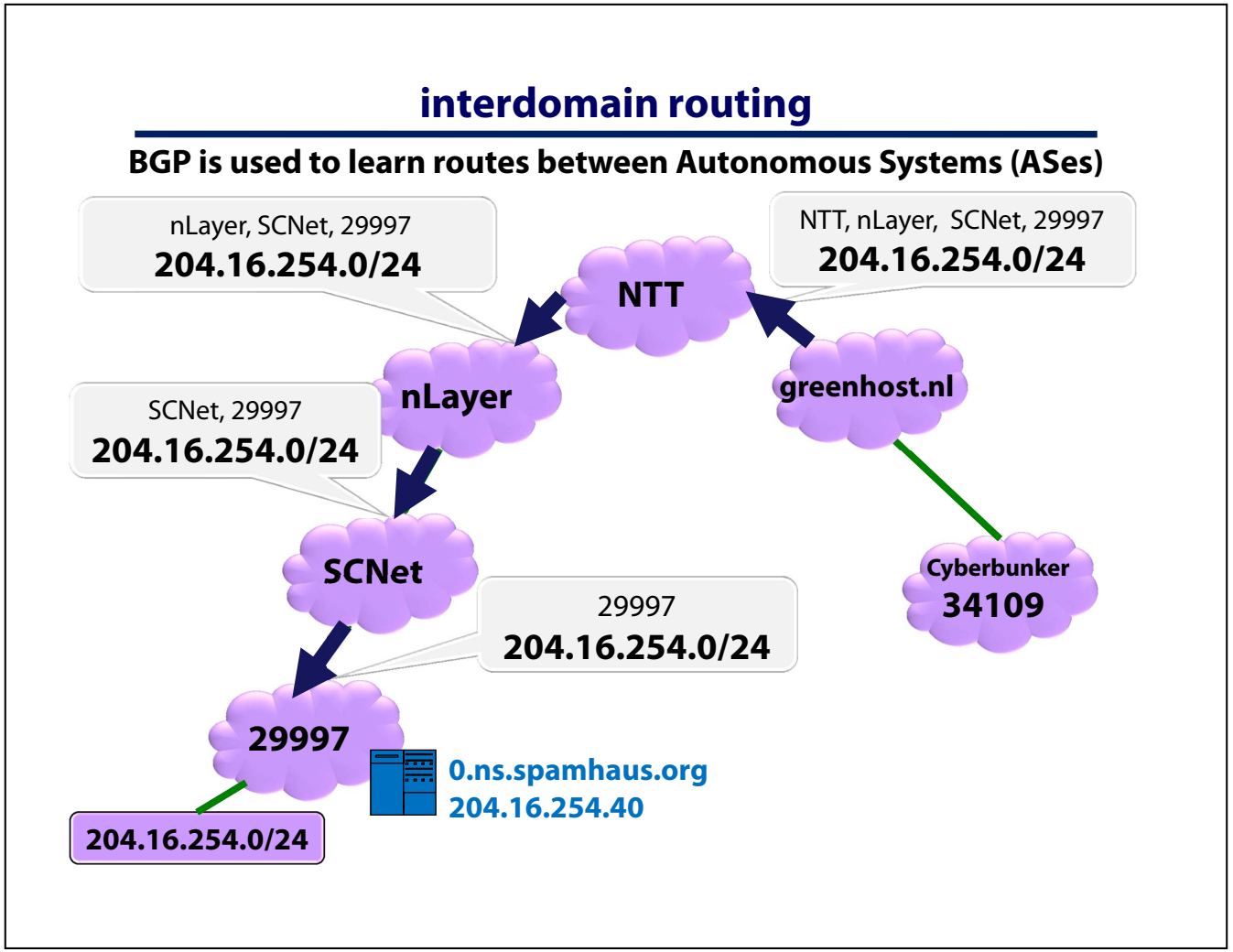
- Resource Public Key Infrastructure (RPKI)
  - A framework to support improved BGP security:
    1. A secure way to map AS numbers to IP prefixes.
    2. A distributed repository system for storing and disseminating the mappings.
- RPKI operations
  - RPKI relies on cryptographic certificates (X.509)
  - The certificate infrastructure mimics the way IP prefixes are distributed: from IANA, to Regional Internet Registries (RIR), to end-customers.
  - A Route Origination Authorization (ROA) states which AS is authorised to originate certain IP prefixes.



NIST RPKI Monitor: RPKI-ROV Analysis **Protocol:** IPv4 **RIR:** All **Date:** 2022-04-08 06:00

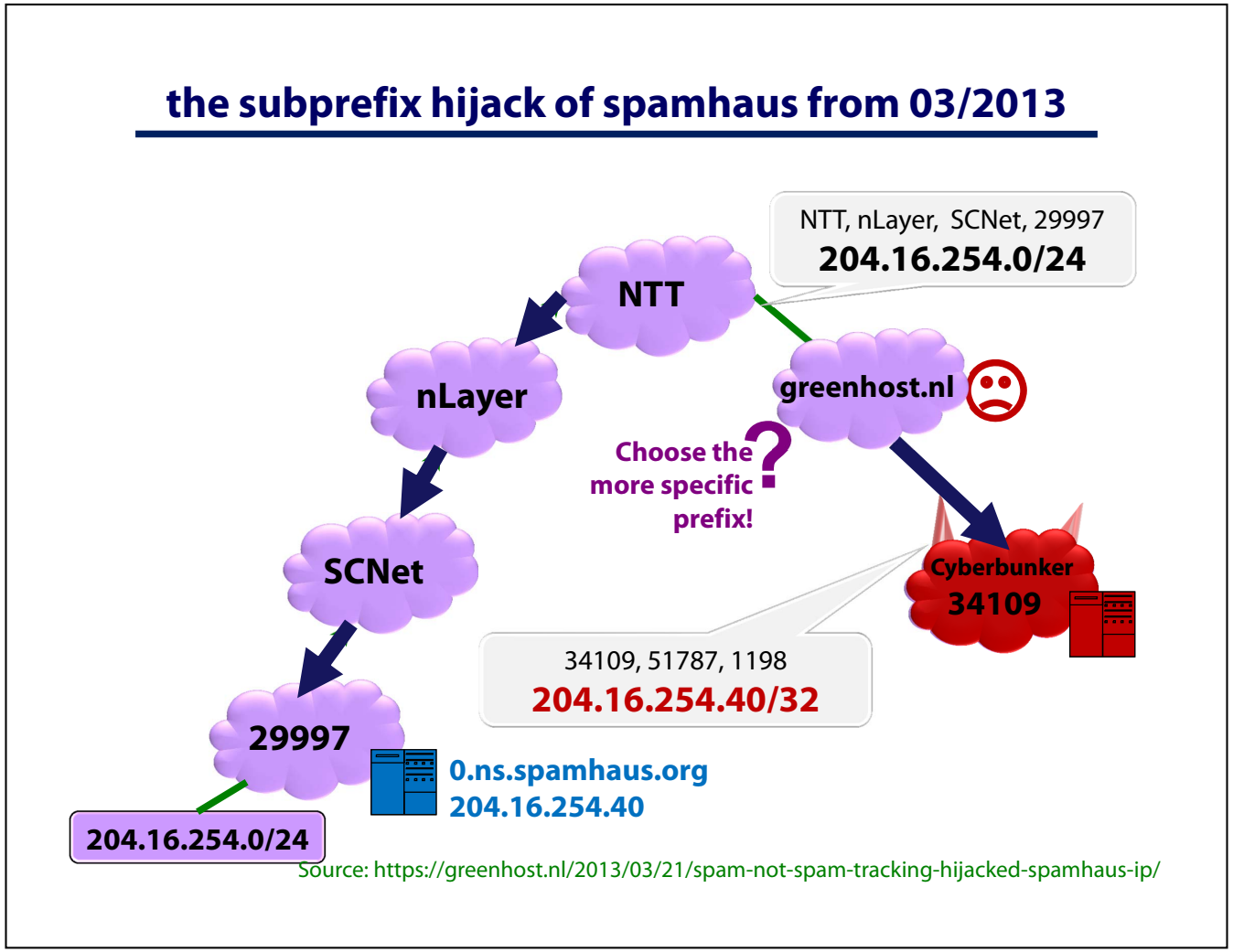
Source: https://rpki-monitor.antd.nist.gov

Let's look back at an example of BGP hijack



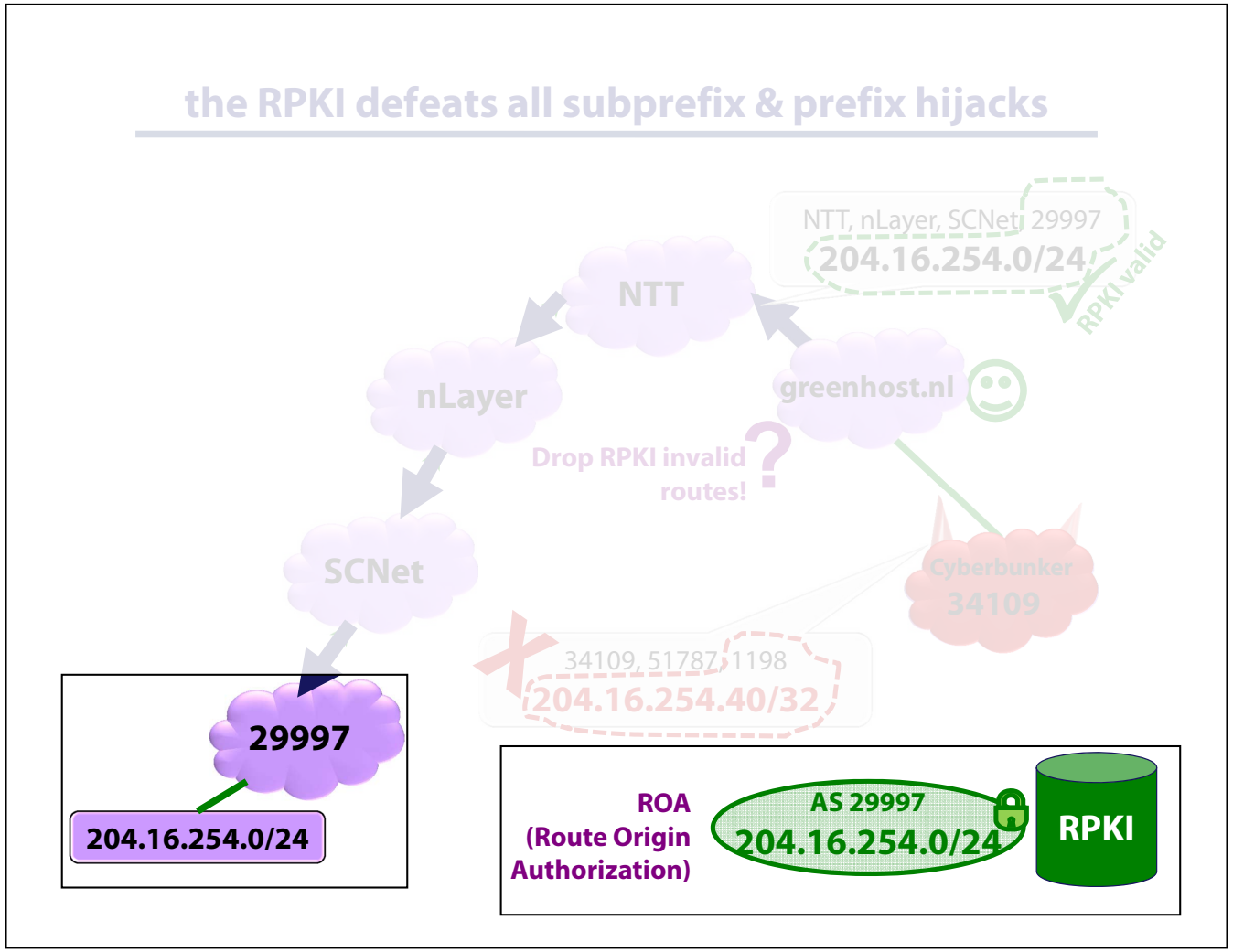
Source: Sharon Goldberg, "The Transition to BGP Security. Is the Juice Worth the Squeeze?"

Without RPKI, a more-specific attack by AS34109 successfully manages to attract the traffic



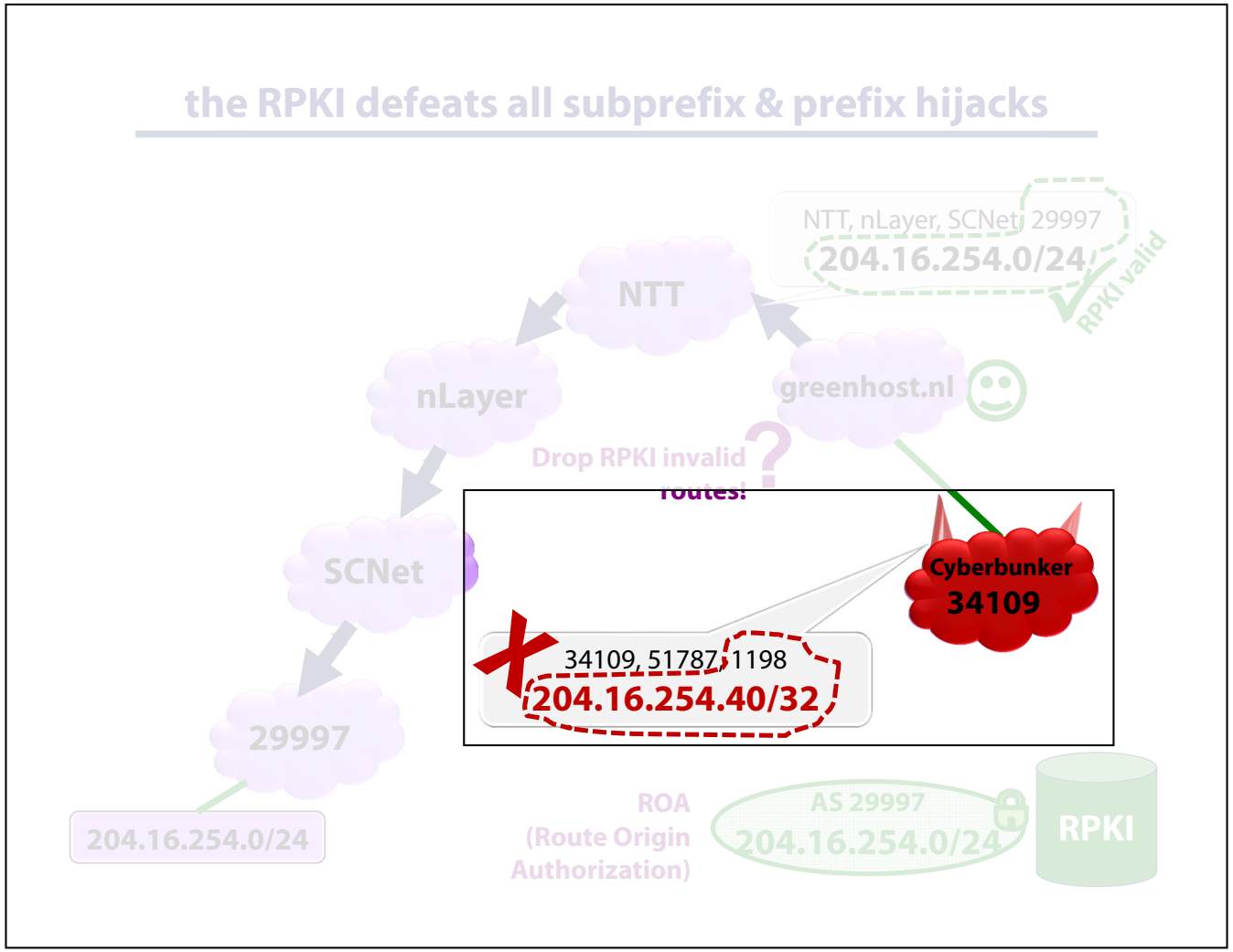
Source: Sharon Goldberg, "The Transition to BGP Security. Is the Juice Worth the Squeeze?"

Let's assume now that AS 29997 registers (204.16.254.0/24-32, 29997) as a new ROA



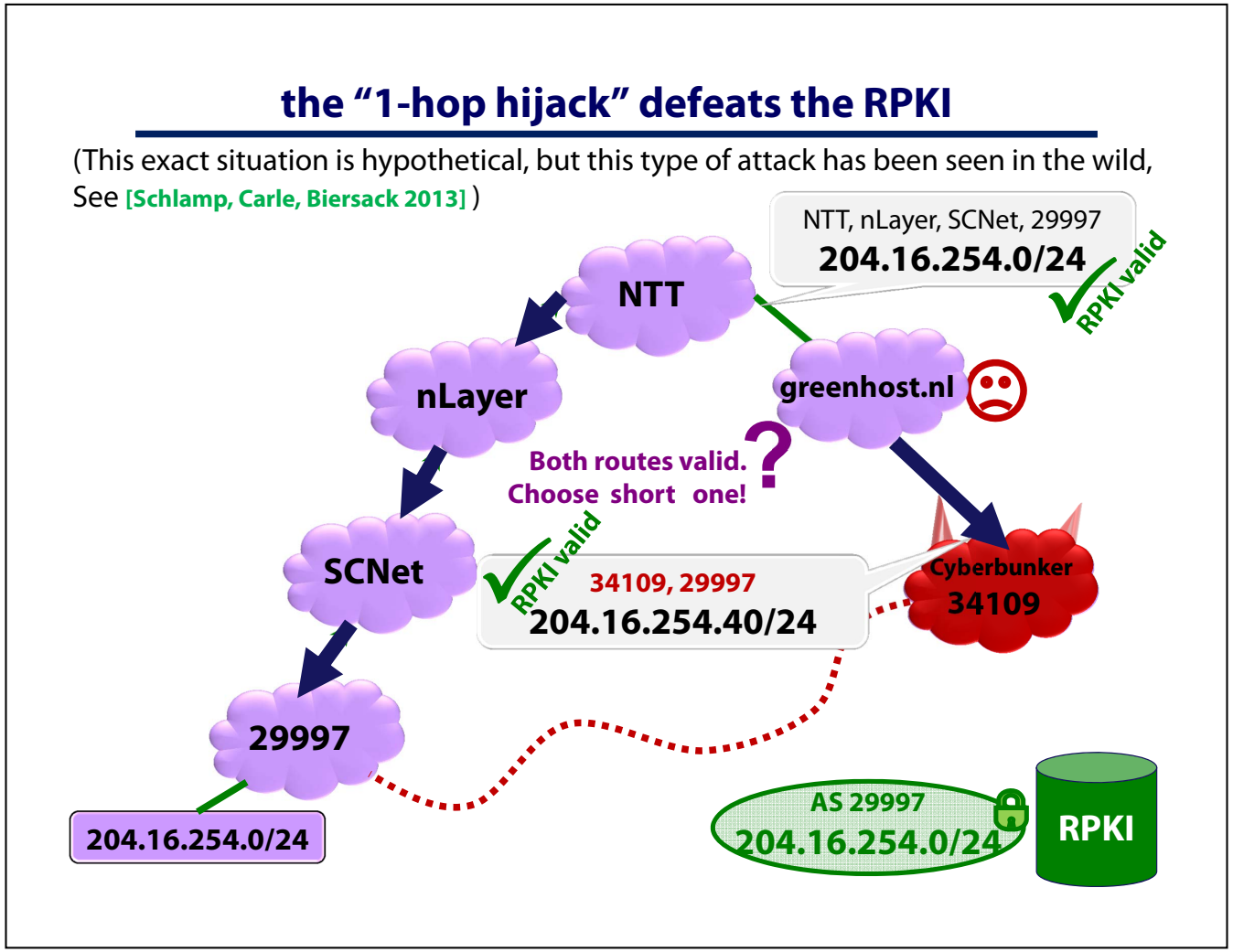
Source: Sharon Goldberg, "The Transition to BGP Security. Is the Juice Worth the Squeeze?"

The hijacked announcement is now *INVALID*



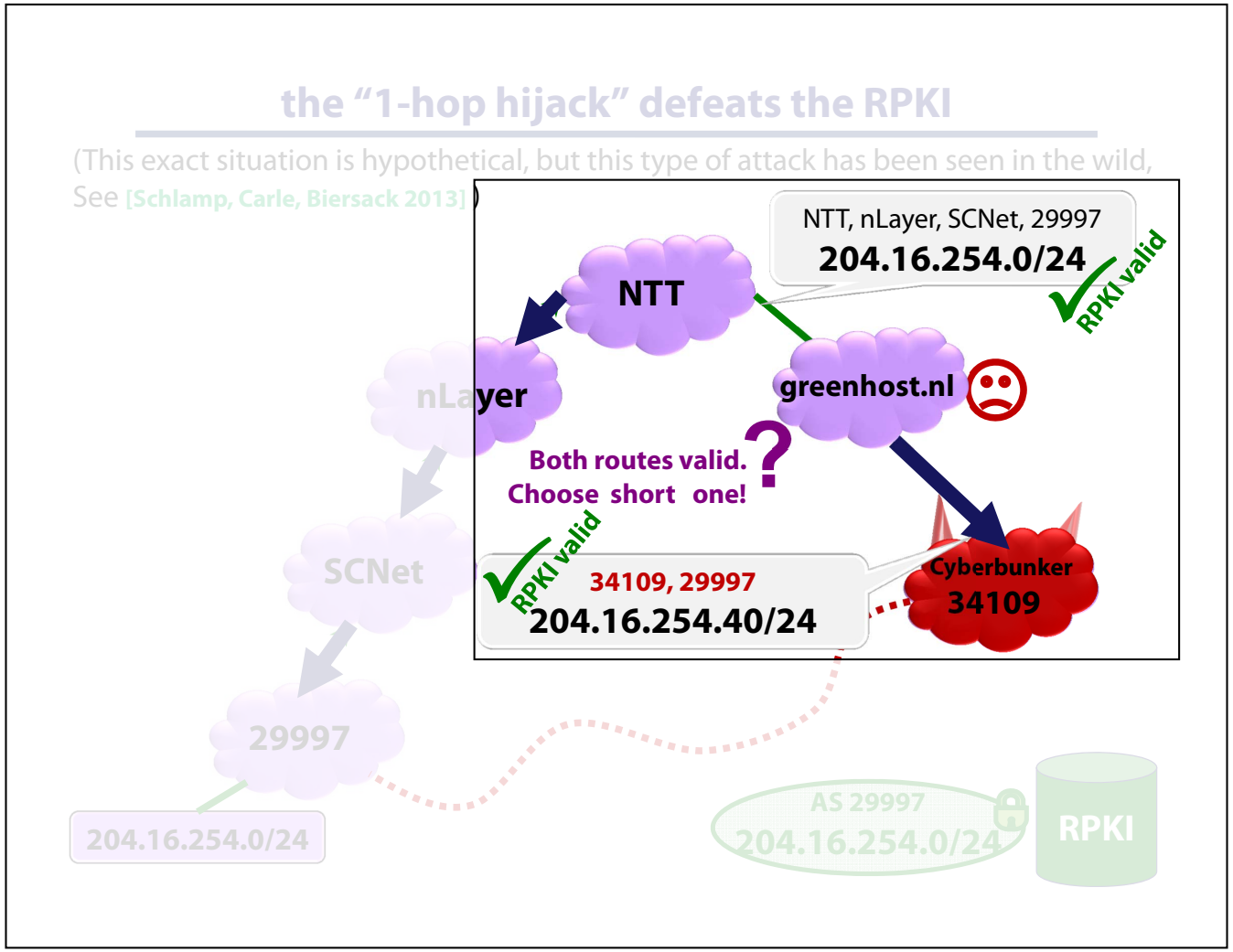
Source: Sharon Goldberg, "The Transition to BGP Security. Is the Juice Worth the Squeeze?"

But what if AS34109 announce AS29997 as the origin?



Source: Sharon Goldberg, "The Transition to BGP Security. Is the Juice Worth the Squeeze?"

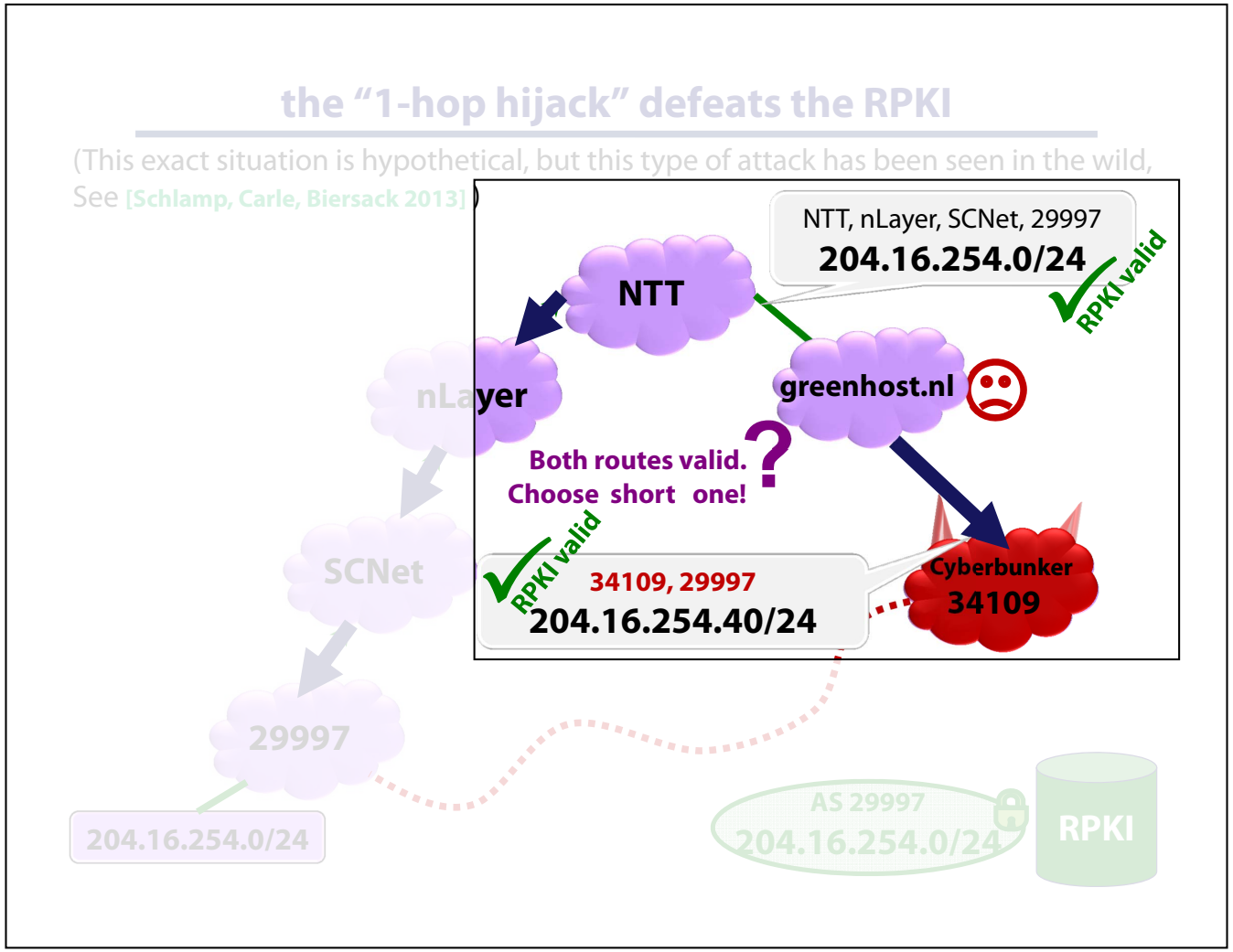
Here greenhost.nl receives 2 valid RPKI routes: one via NTT and another one via 34109



Source: Sharon Goldberg, "The Transition to BGP Security. Is the Juice Worth the Squeeze?"

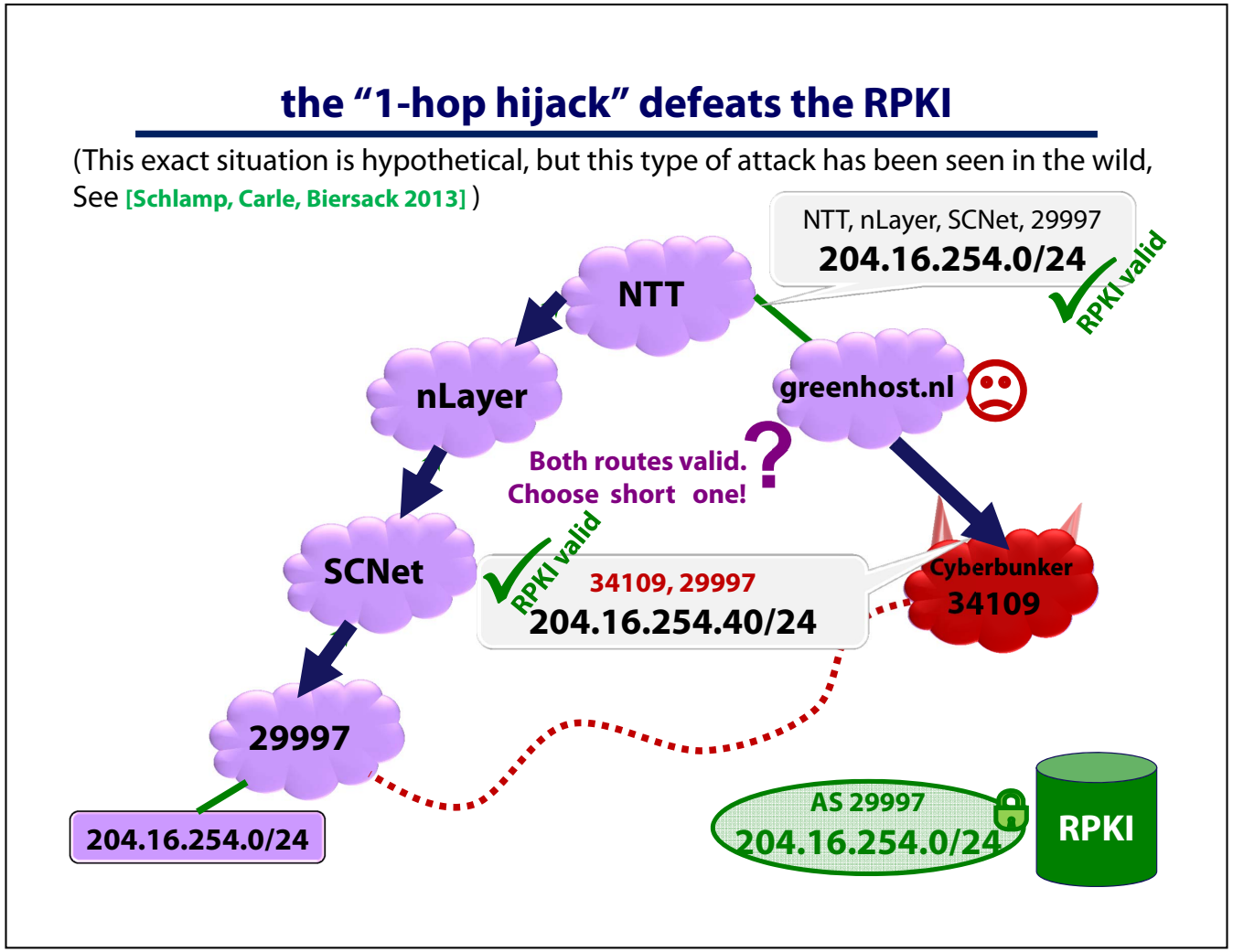
As the route via 34109 has a shorter path,

it is preferred… the attack works again!



Source: Sharon Goldberg, "The Transition to BGP Security. Is the Juice Worth the Squeeze?"

We see that RPKI does not protect against *all* attacks



Source: Sharon Goldberg, "The Transition to BGP Security. Is the Juice Worth the Squeeze?"

Problems

Reachability

Security

Convergence

Performance

Anomalies

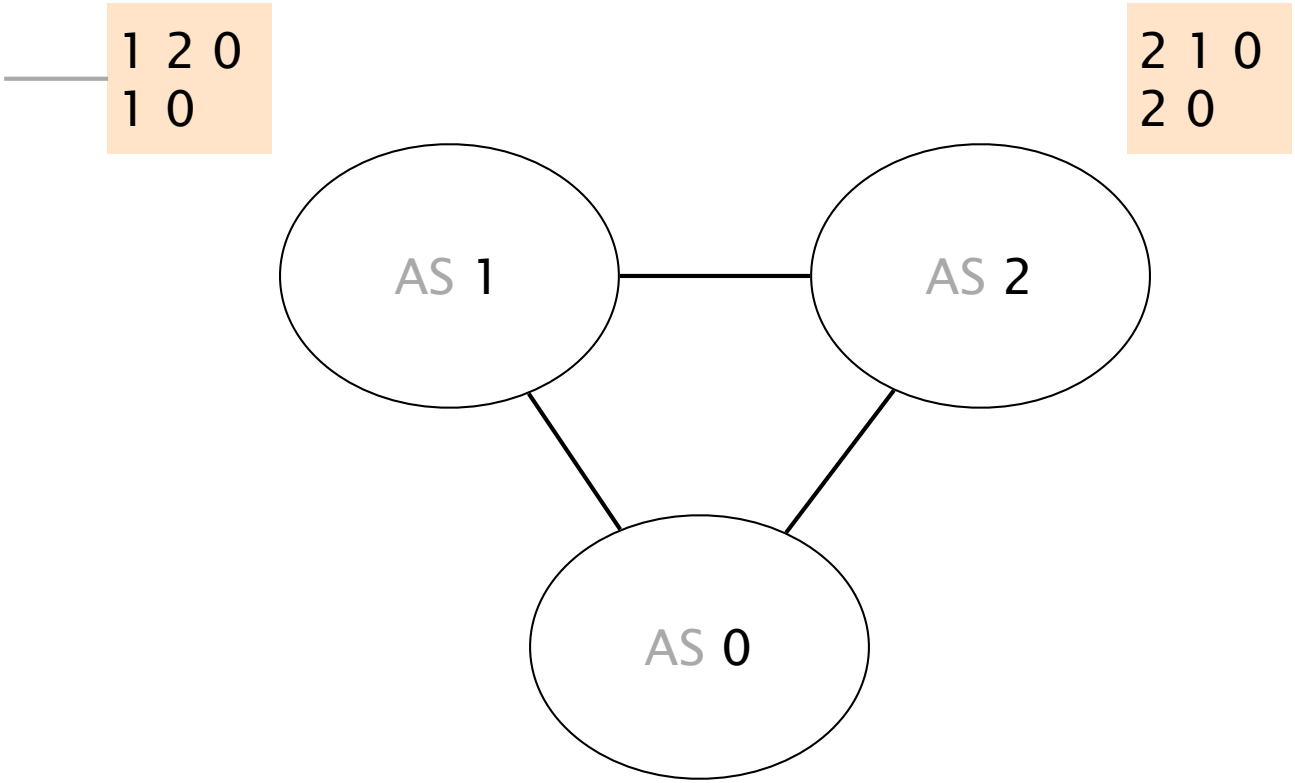
Relevance

With arbitrary policies,
BGP may have multiple stable states

preference list

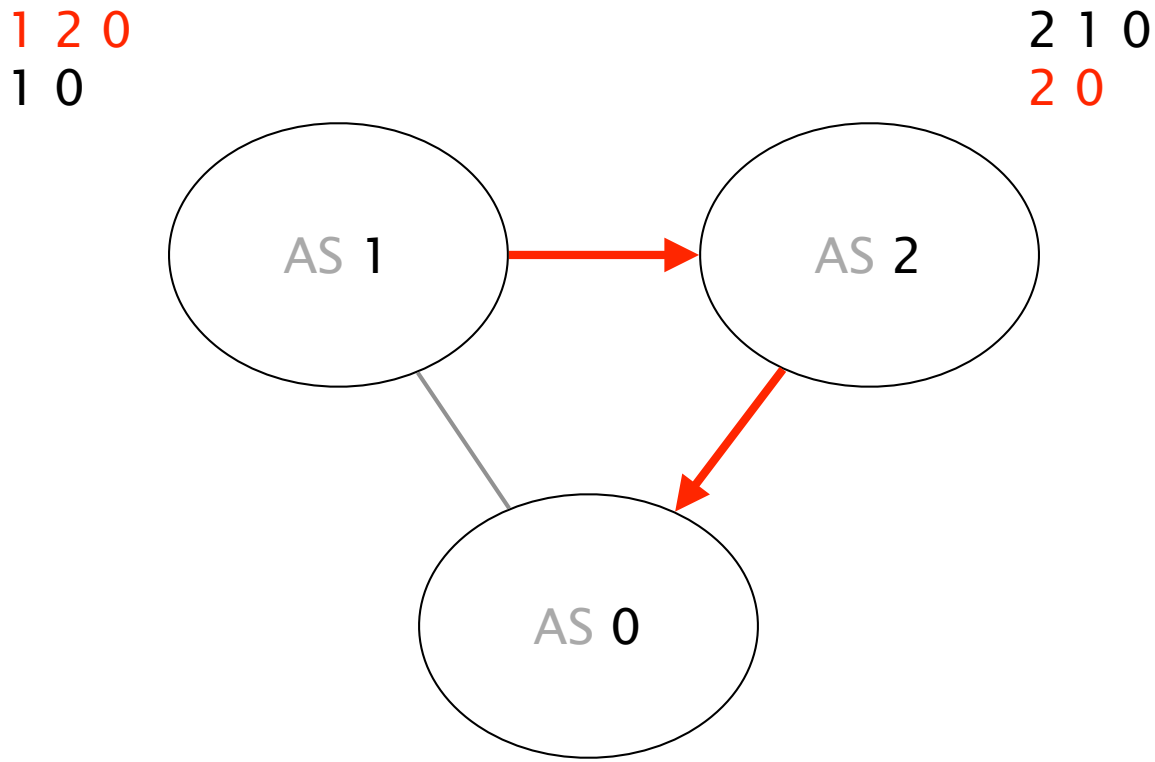
1 prefers to reach 0

via 2 rather than directly



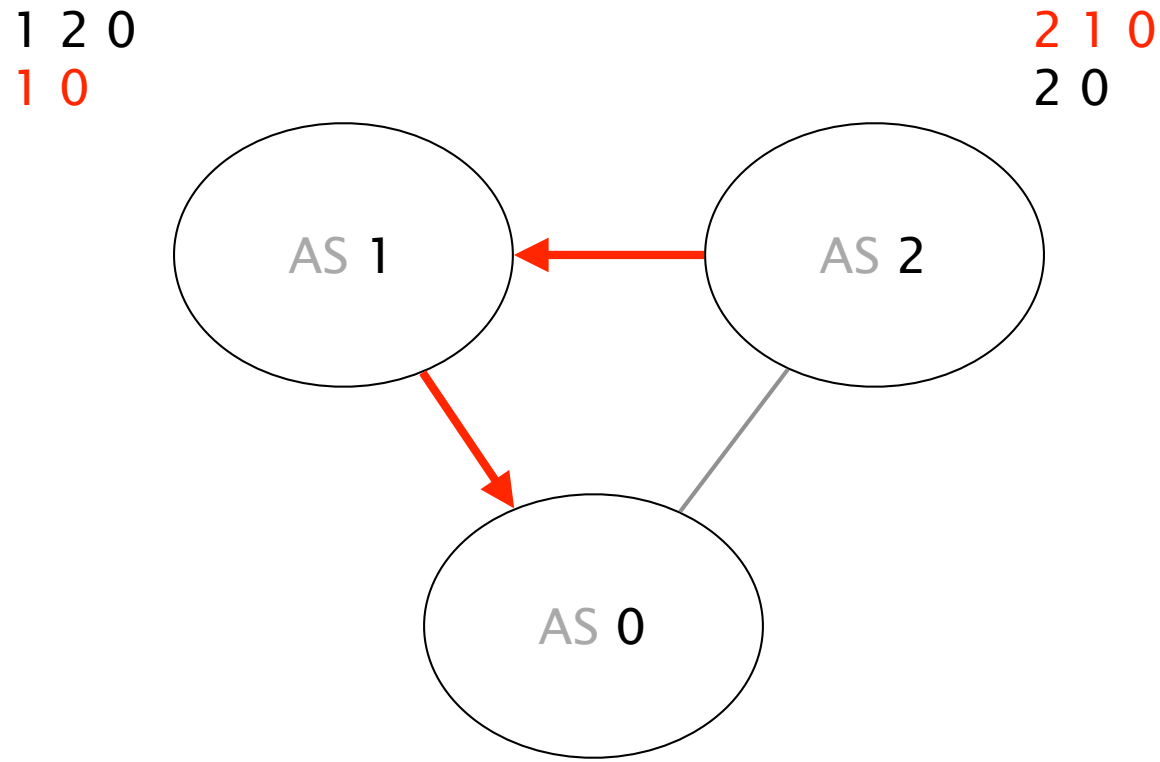
If AS2 is the first to advertise 2 0,

the system stabilizes in a state where AS 1 is happy



If AS1 is the first one to advertise 1 0,

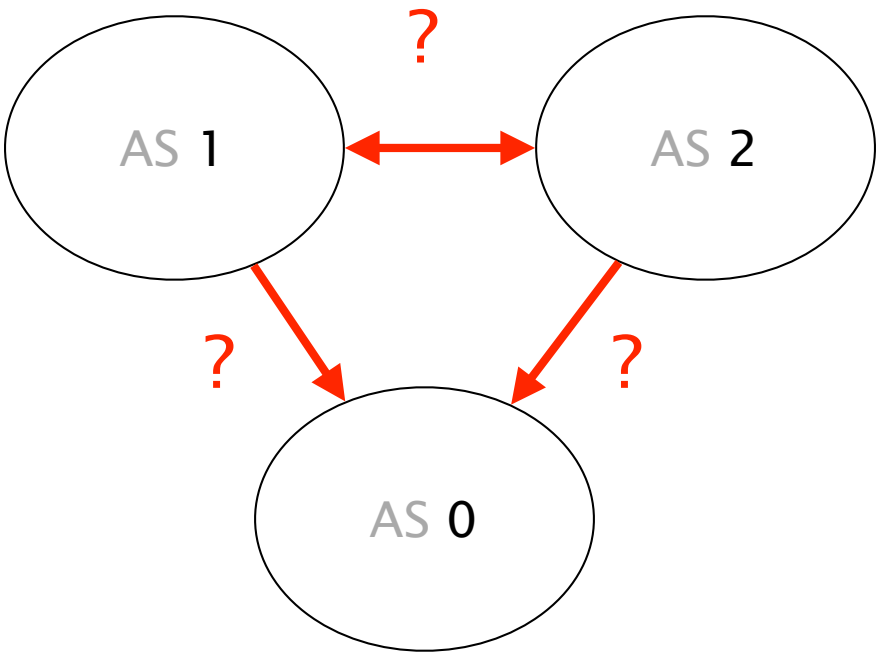
the system stabilizes in a state where AS 2 is happy



The actual assignment depends on the ordering between the messages

Note that AS1/AS2 could change the outcome by manual intervention

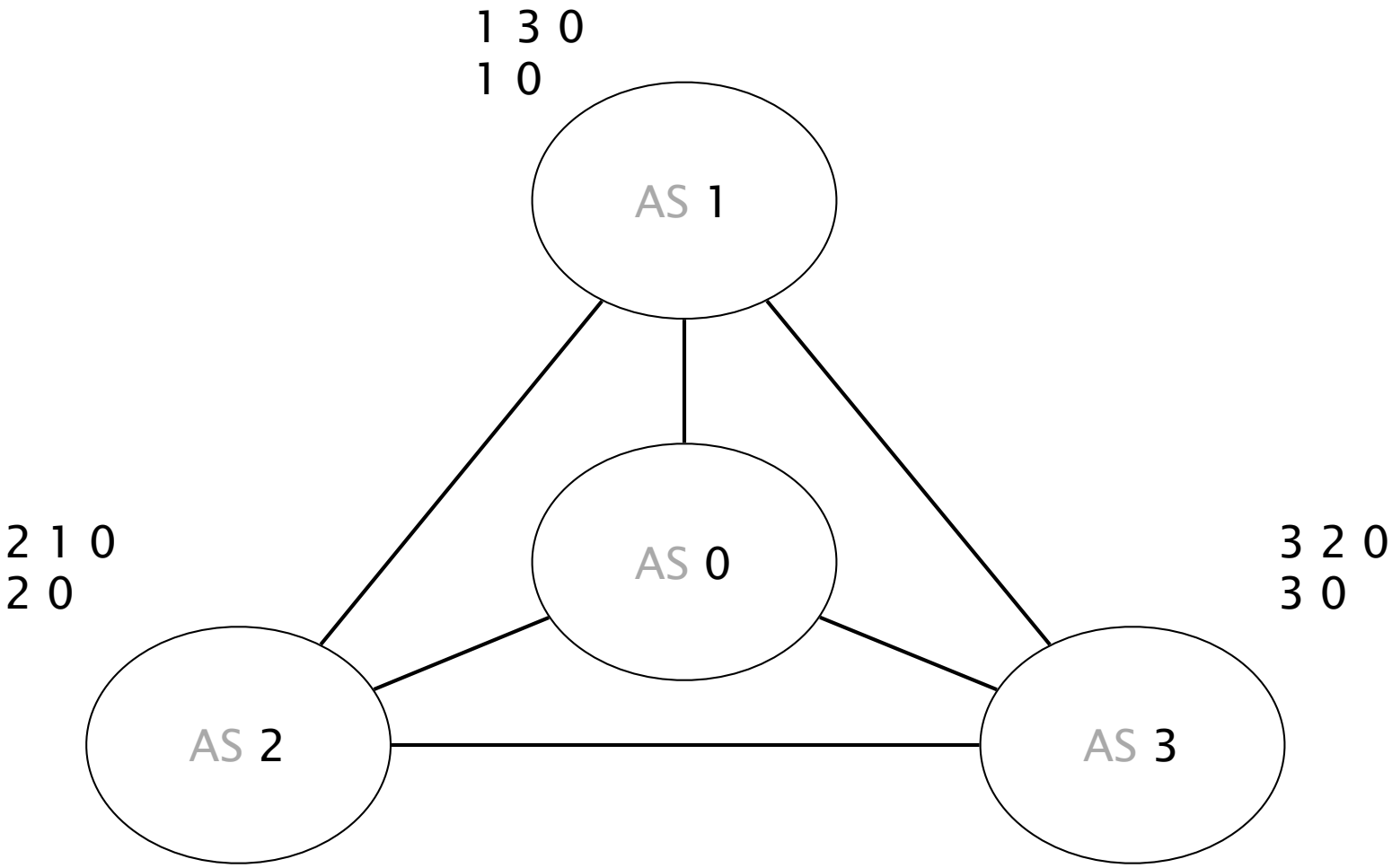
… this is not always possible *



* https://www.nanog.org/meetings/nanog31/presentations/griffin.pdf

With arbitrary policies,

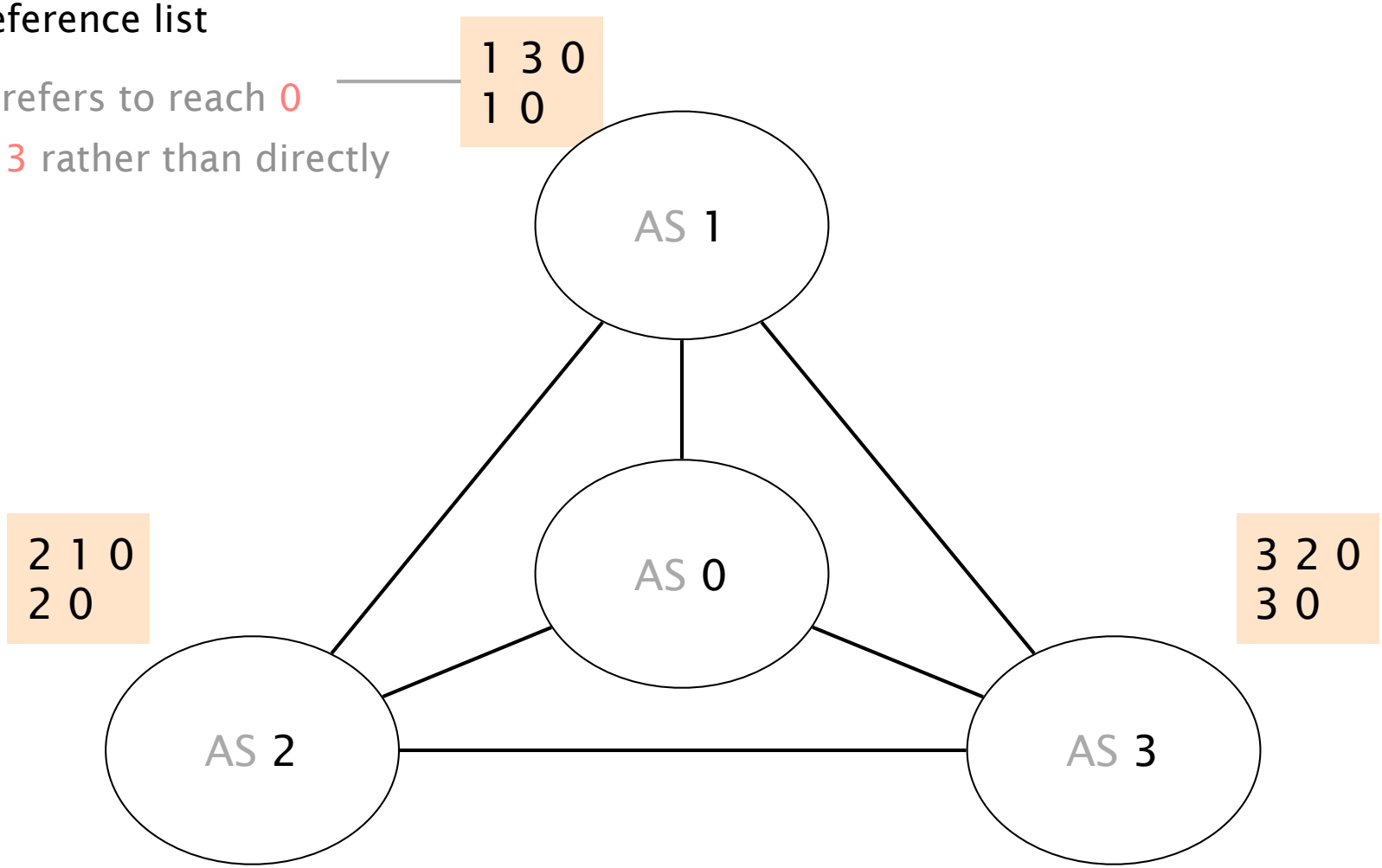
BGP may fail to converge


1 3 0
1 0
AS 1
AS 0
2 1 0
2 0
AS 2
3 2 0
3 0
AS 3

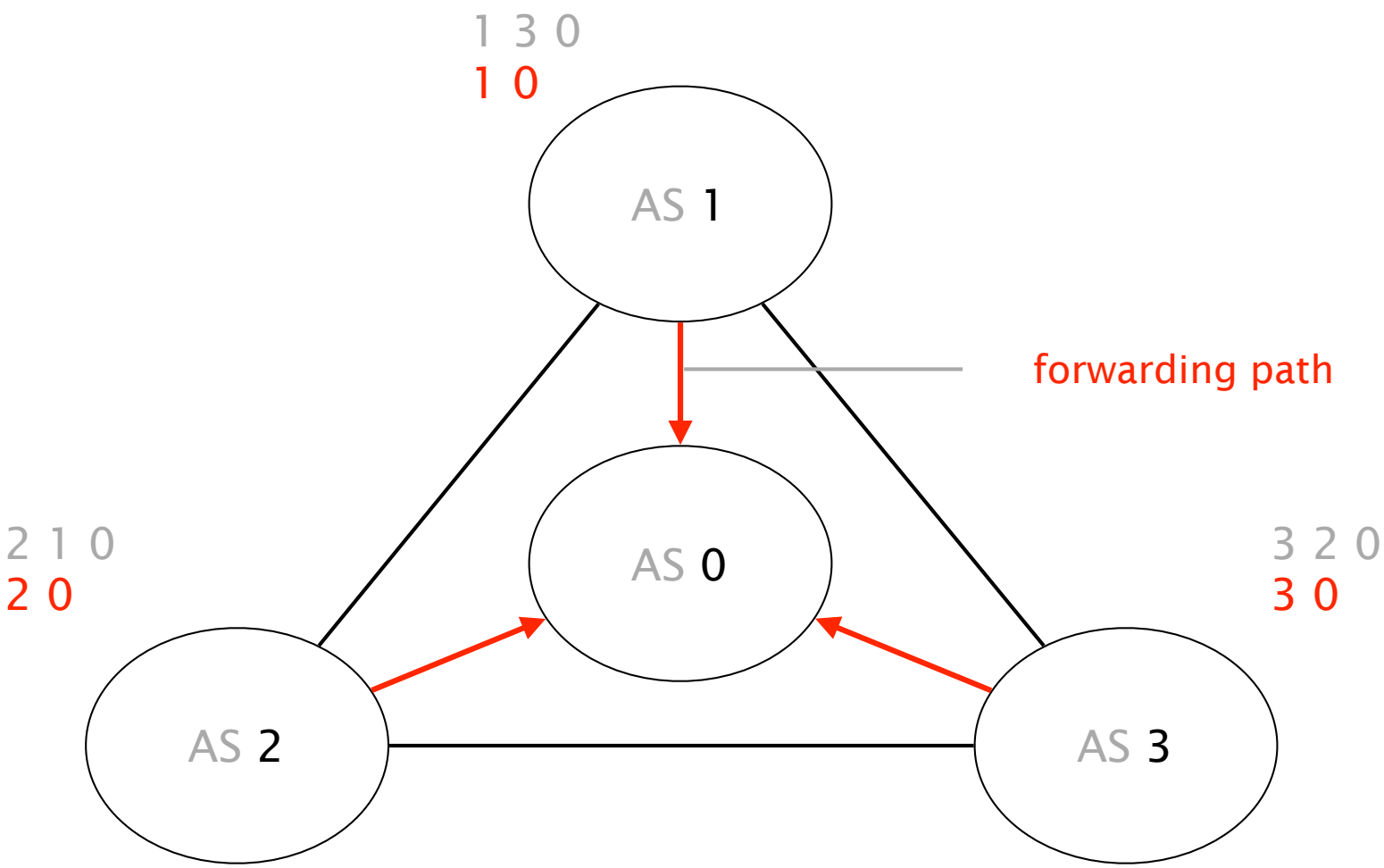
preference list

1 prefers to reach 0

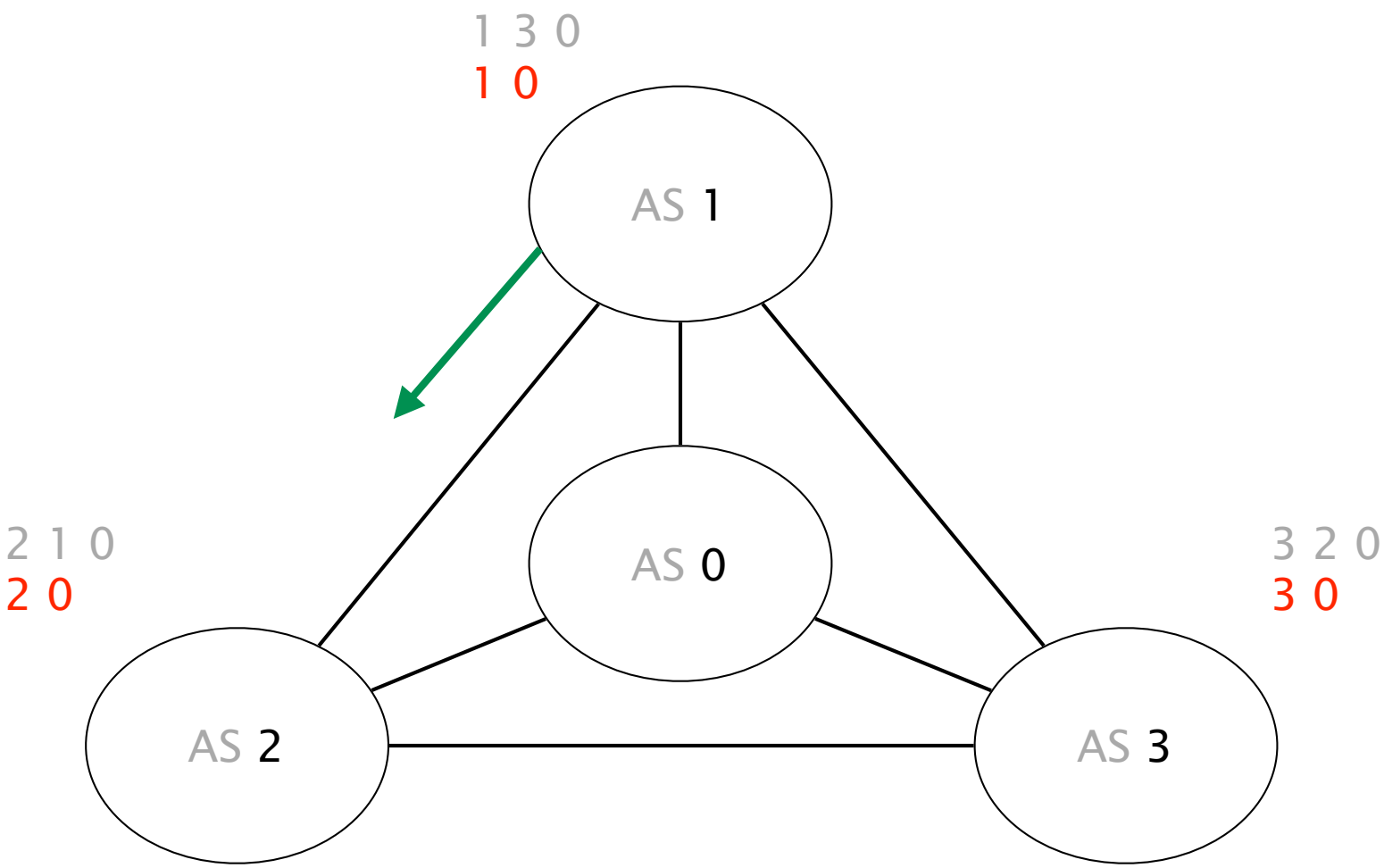
via 3 rather than directly



Initially, all ASes only know the direct route to 0

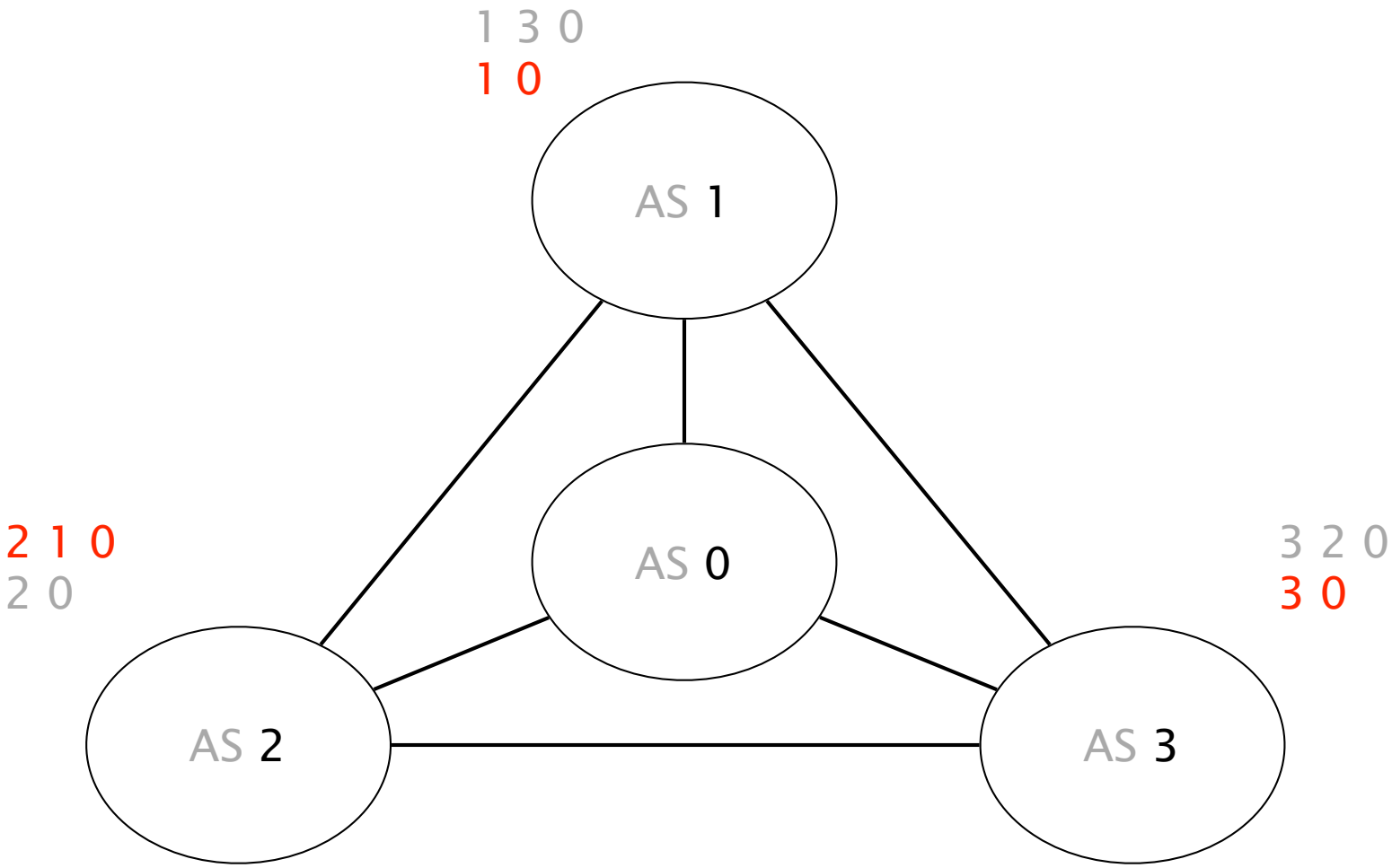


AS 1 advertises its path to AS 2

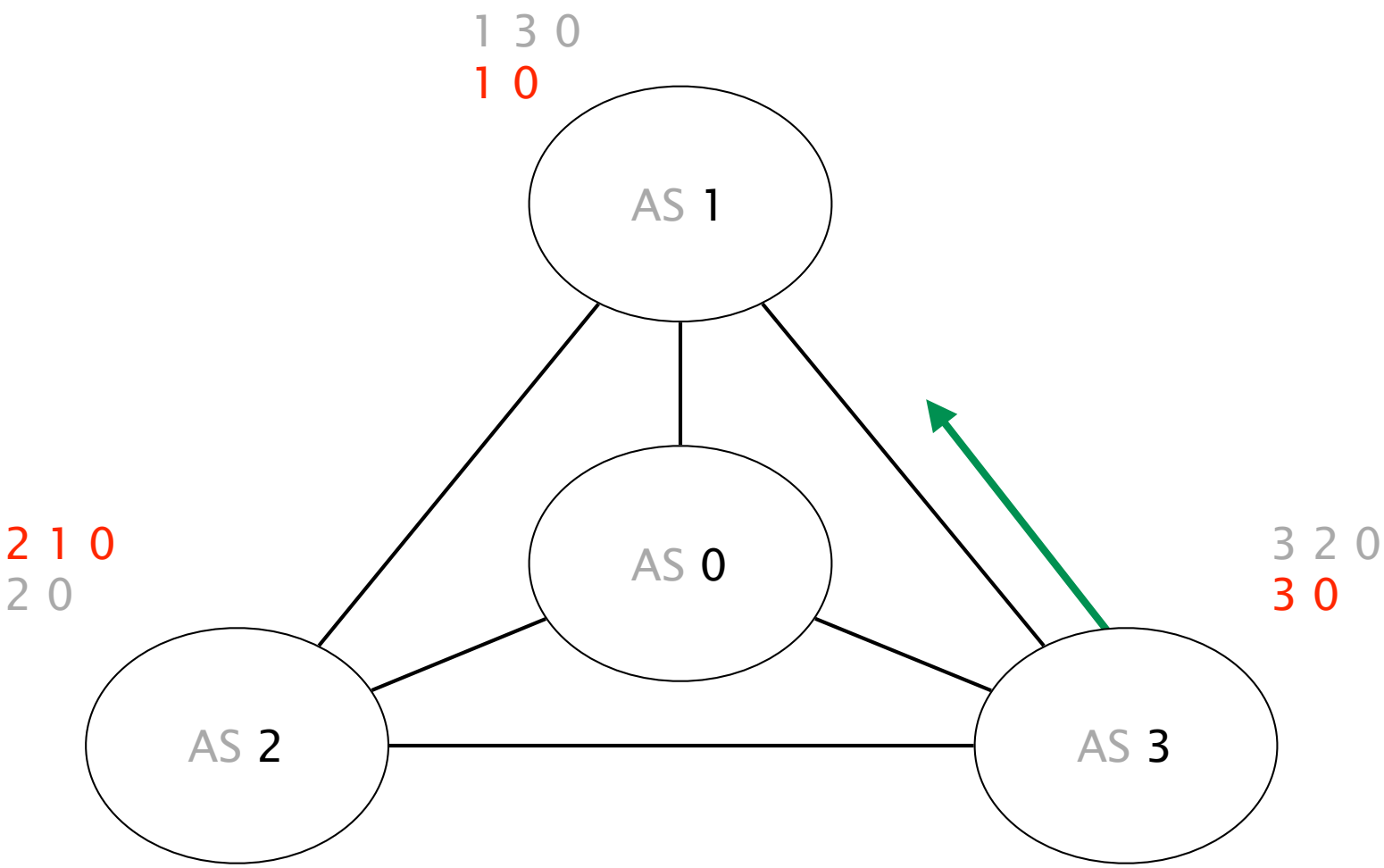


Upon reception,

AS 2 switches to 2 1 0 (preferred)

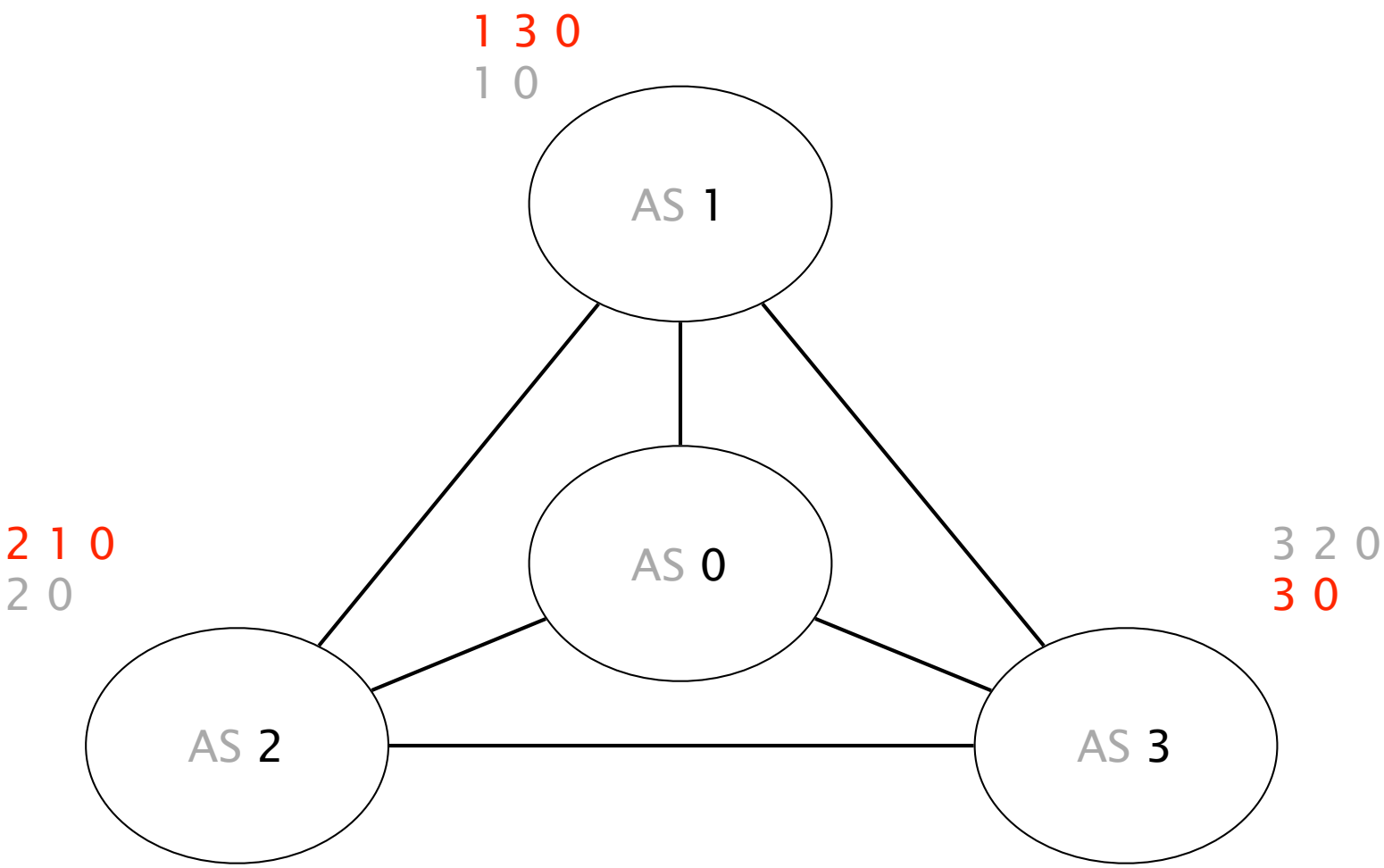


AS 3 advertises its path to AS 1

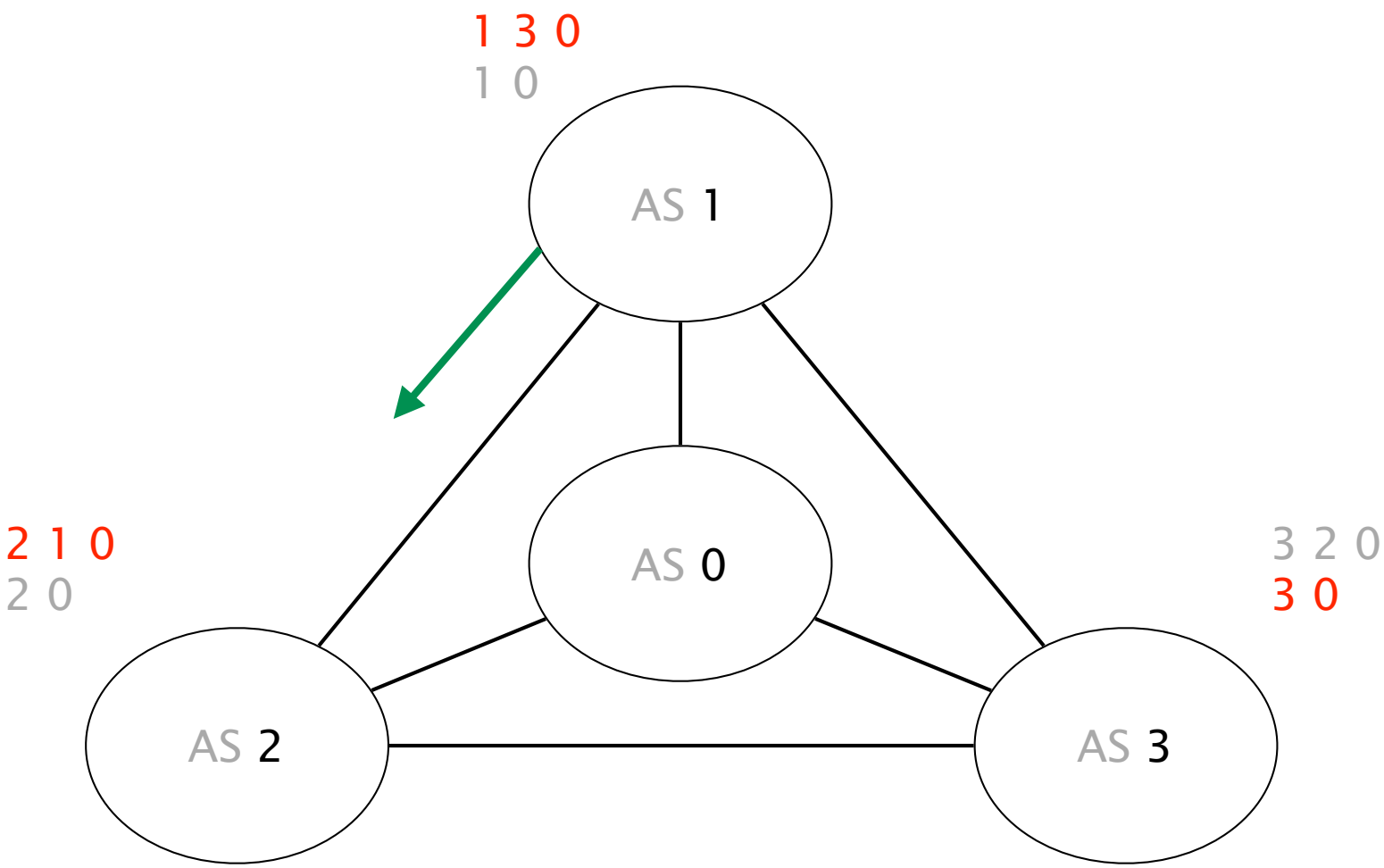


Upon reception,

AS 1 switches to 1 3 0 (preferred)

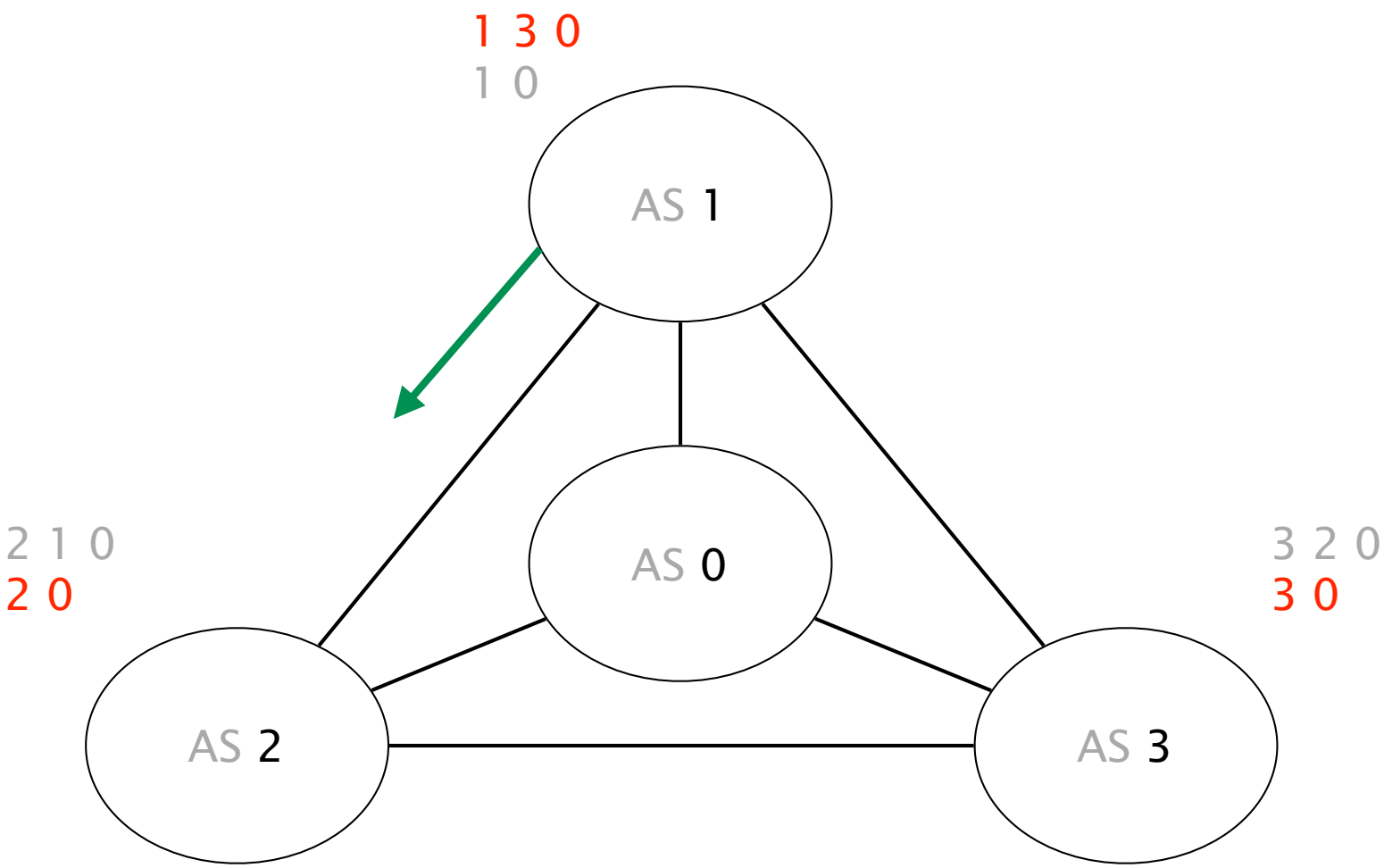


AS 1 advertises its new path 1 3 0 to AS 2

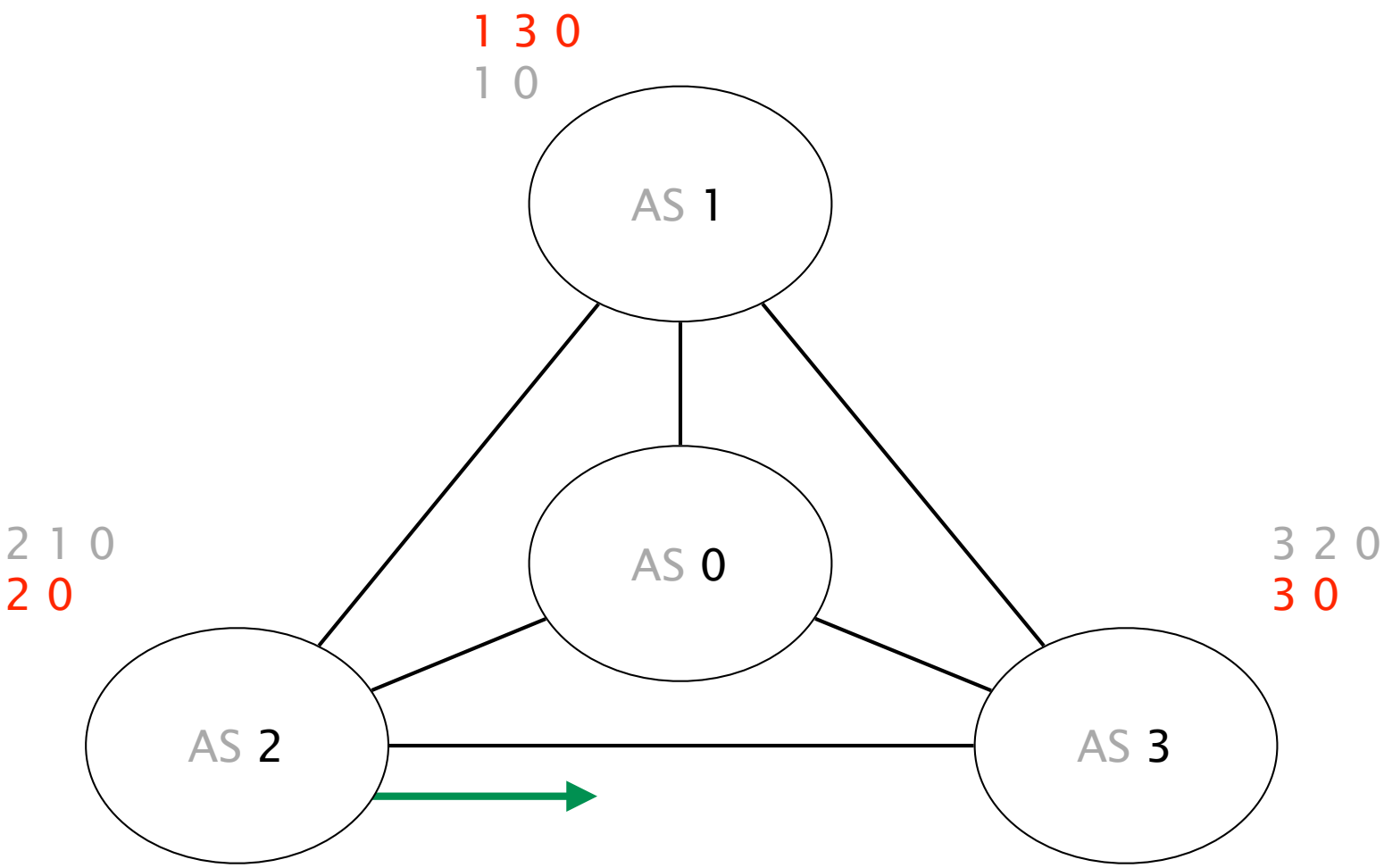


Upon reception,

AS 2 reverts back to its initial path 2 0

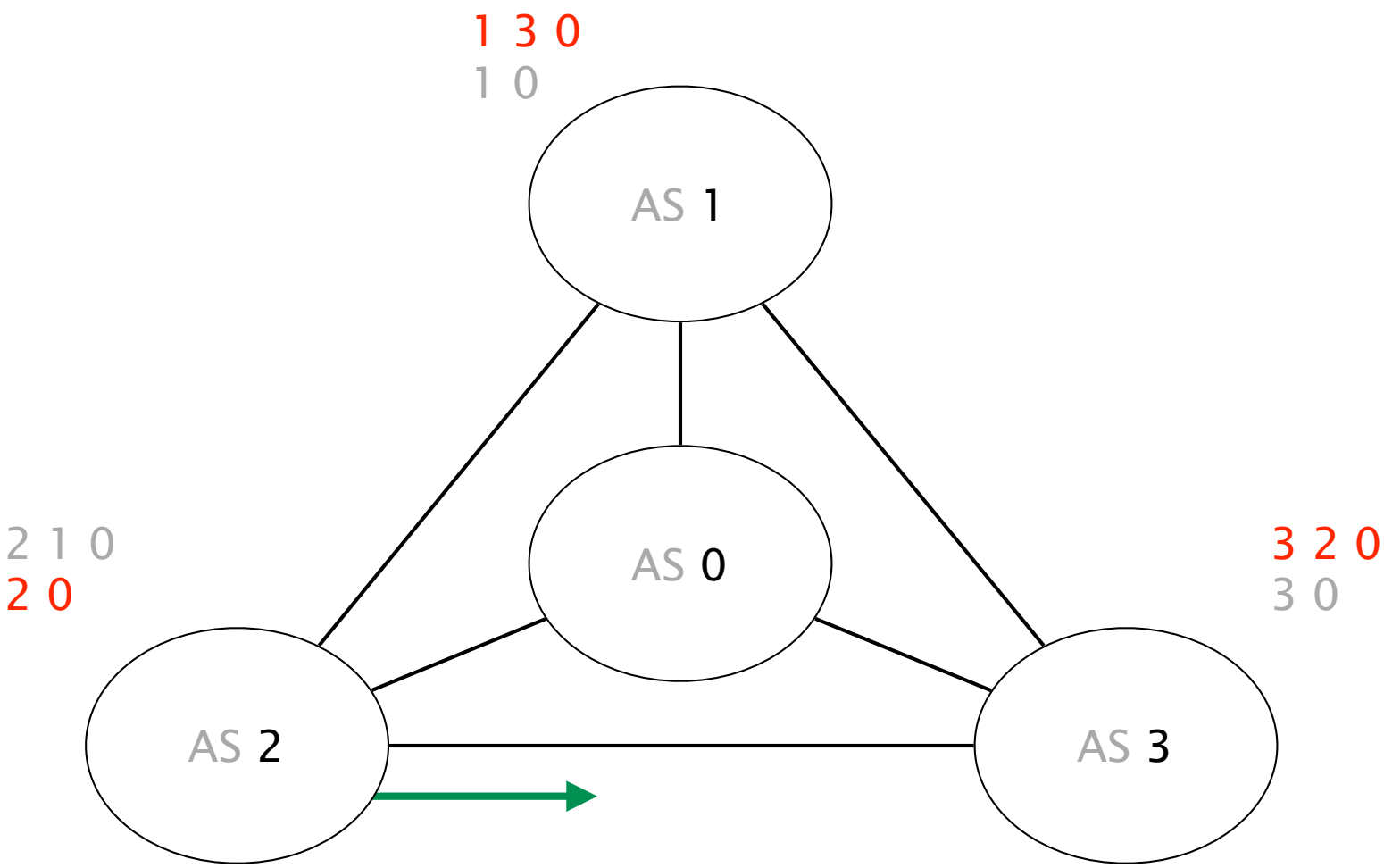


AS 2 advertises its path 2 0 to AS 3

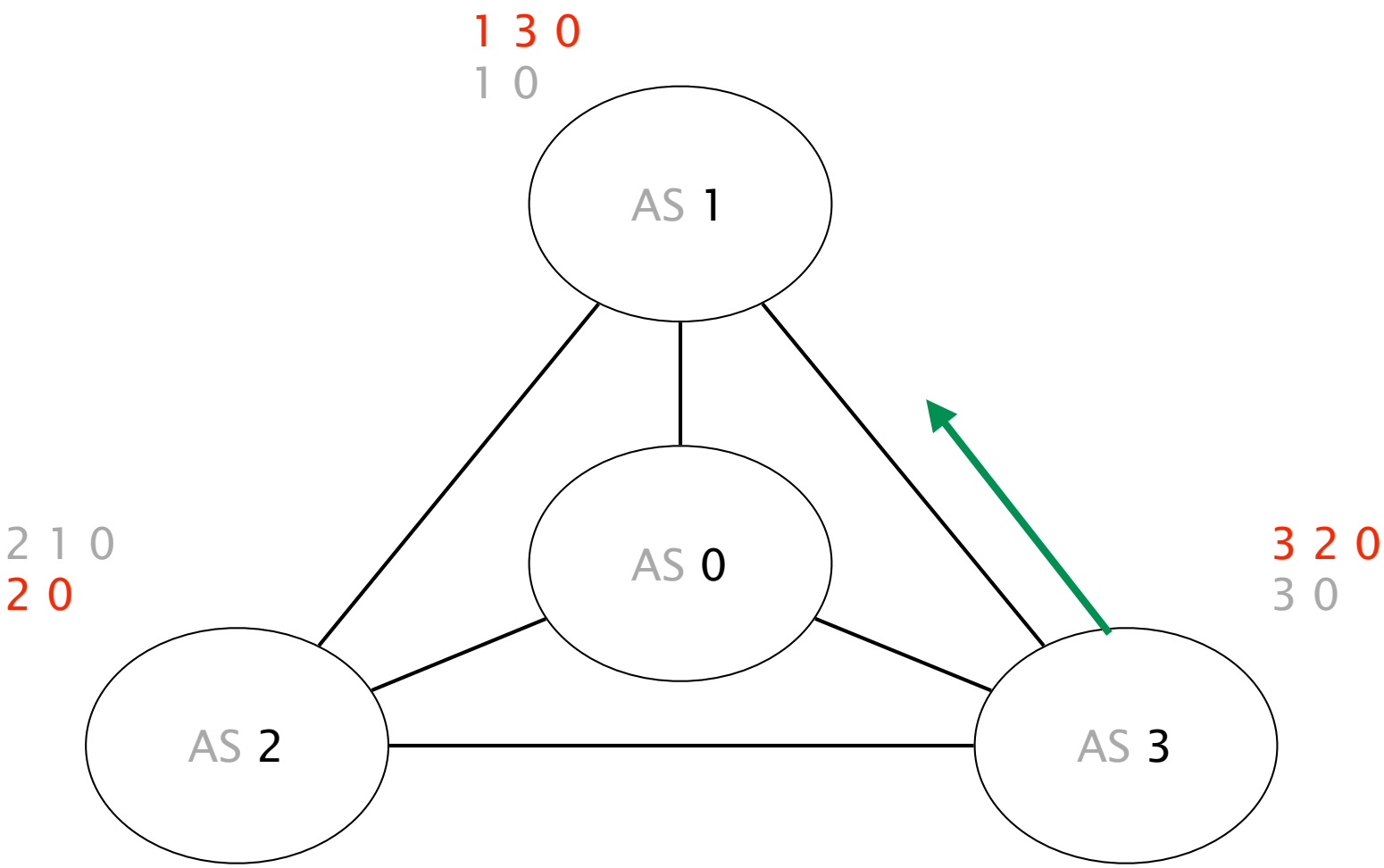


Upon reception,

AS 3 switches to 3 2 0 (preferred)

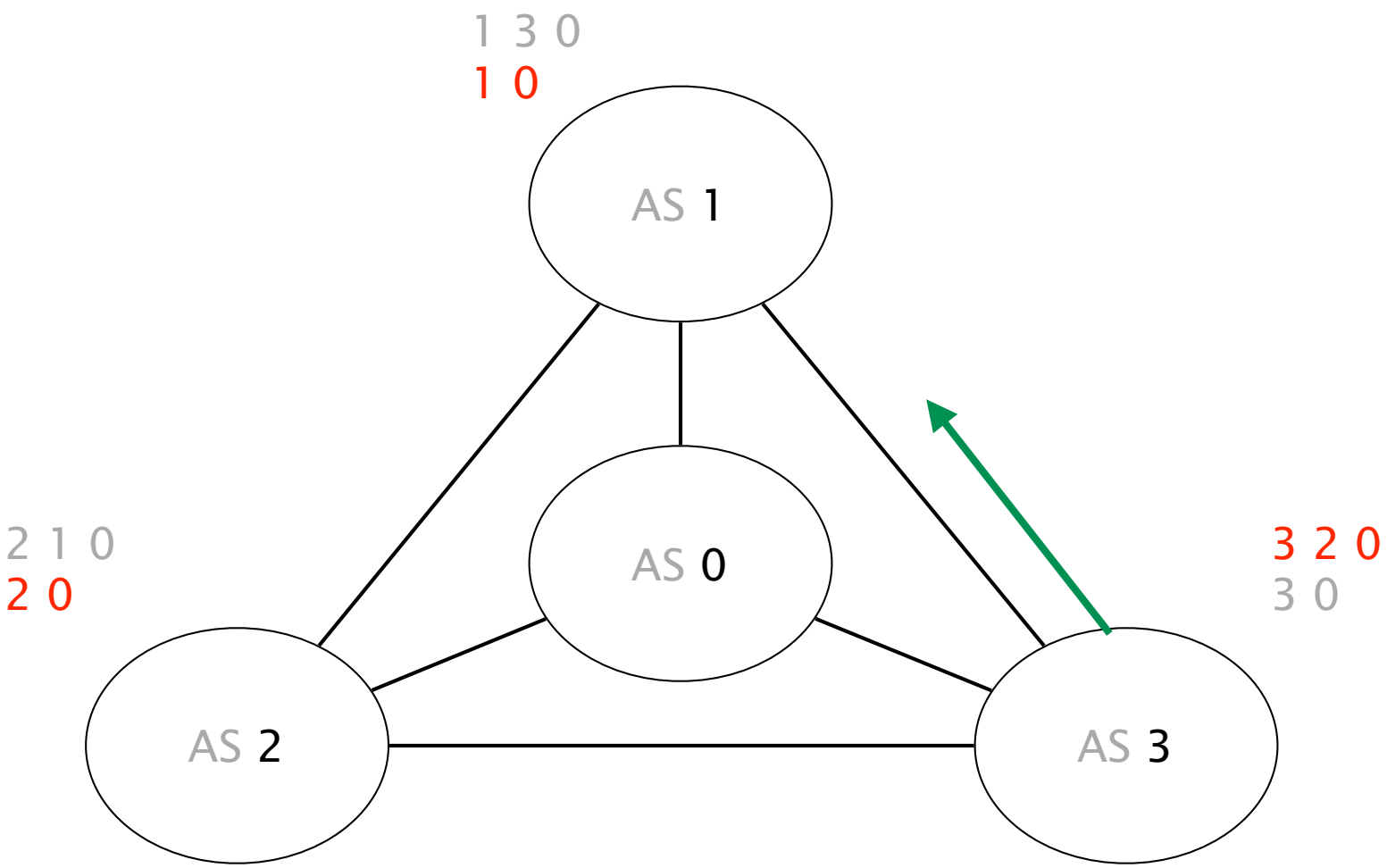


AS 3 advertises its new path 3 2 0 to AS 1

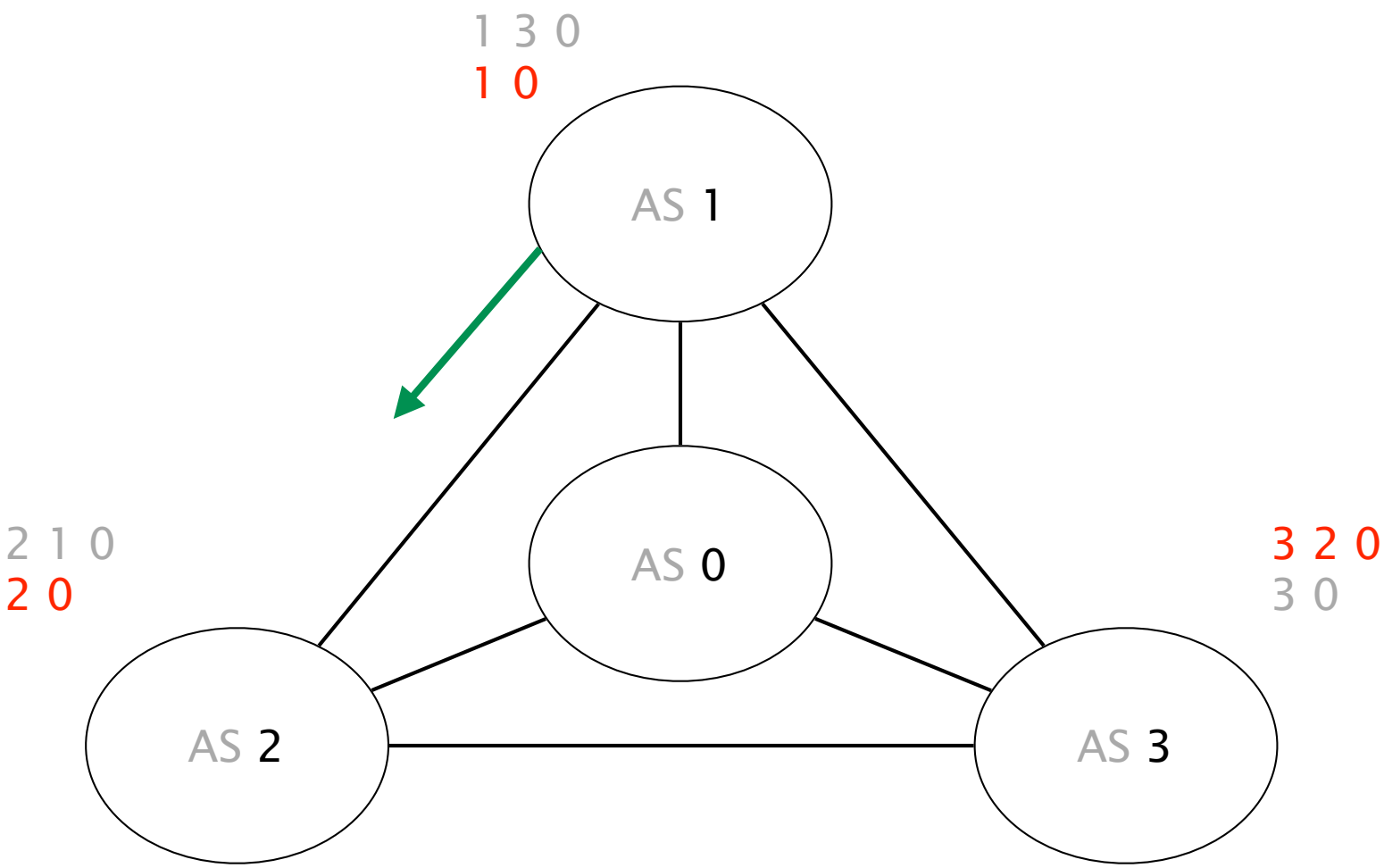


Upon reception,

AS 1 reverts back to 1 0 (initial path)

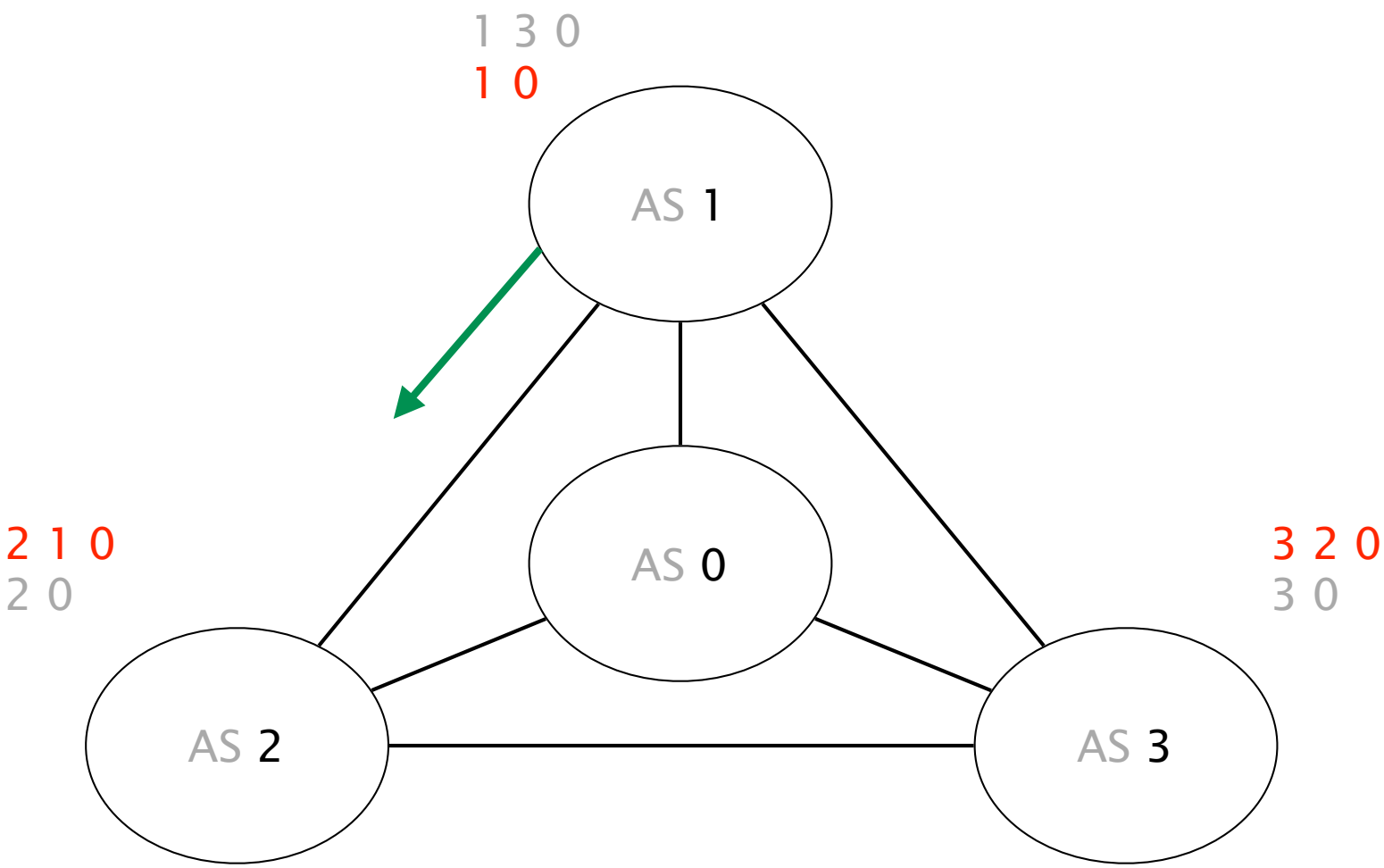


AS 1 advertises its new path 1 0 to AS 2

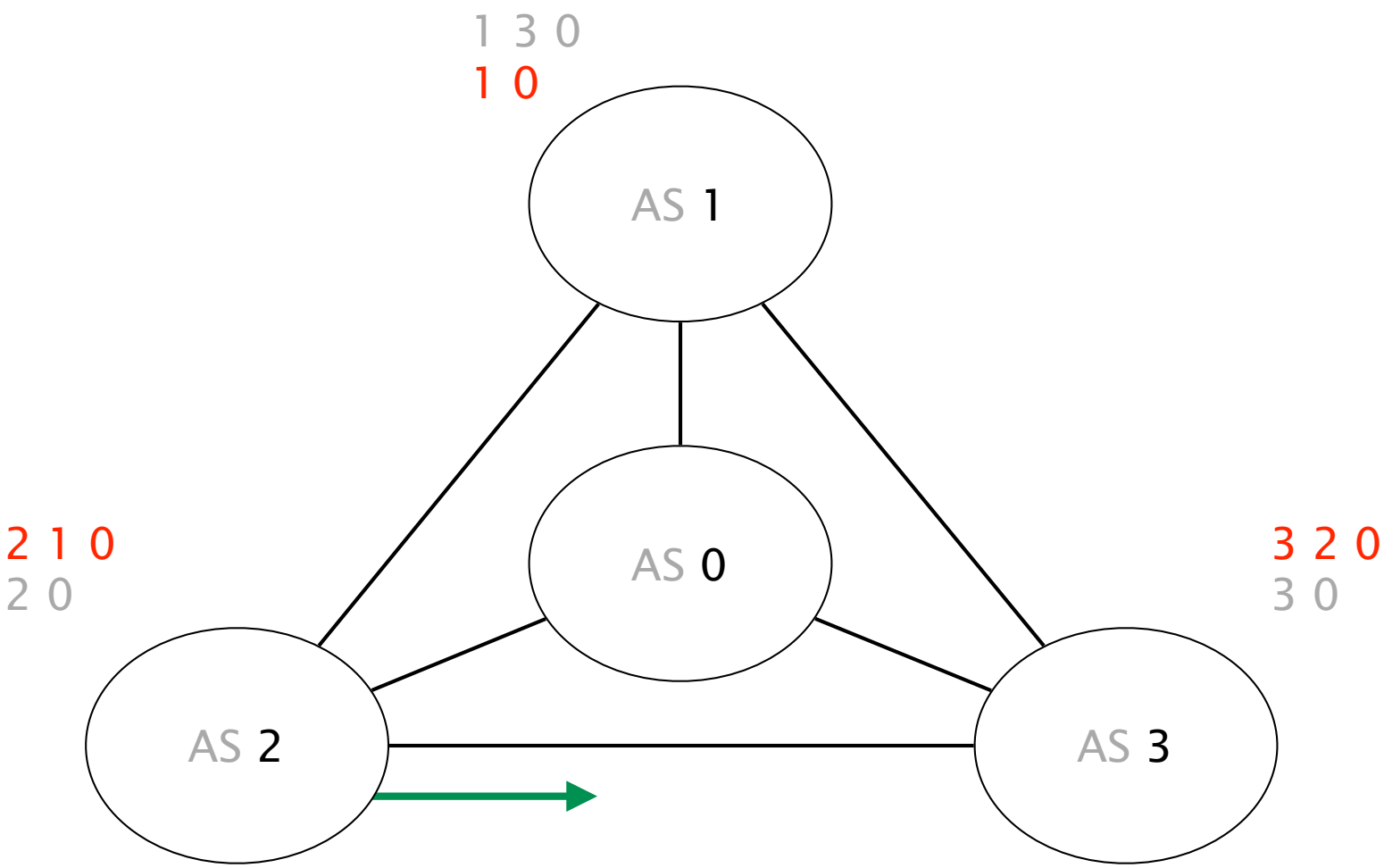


Upon reception,

AS 2 switches to 2 1 0 (preferred)

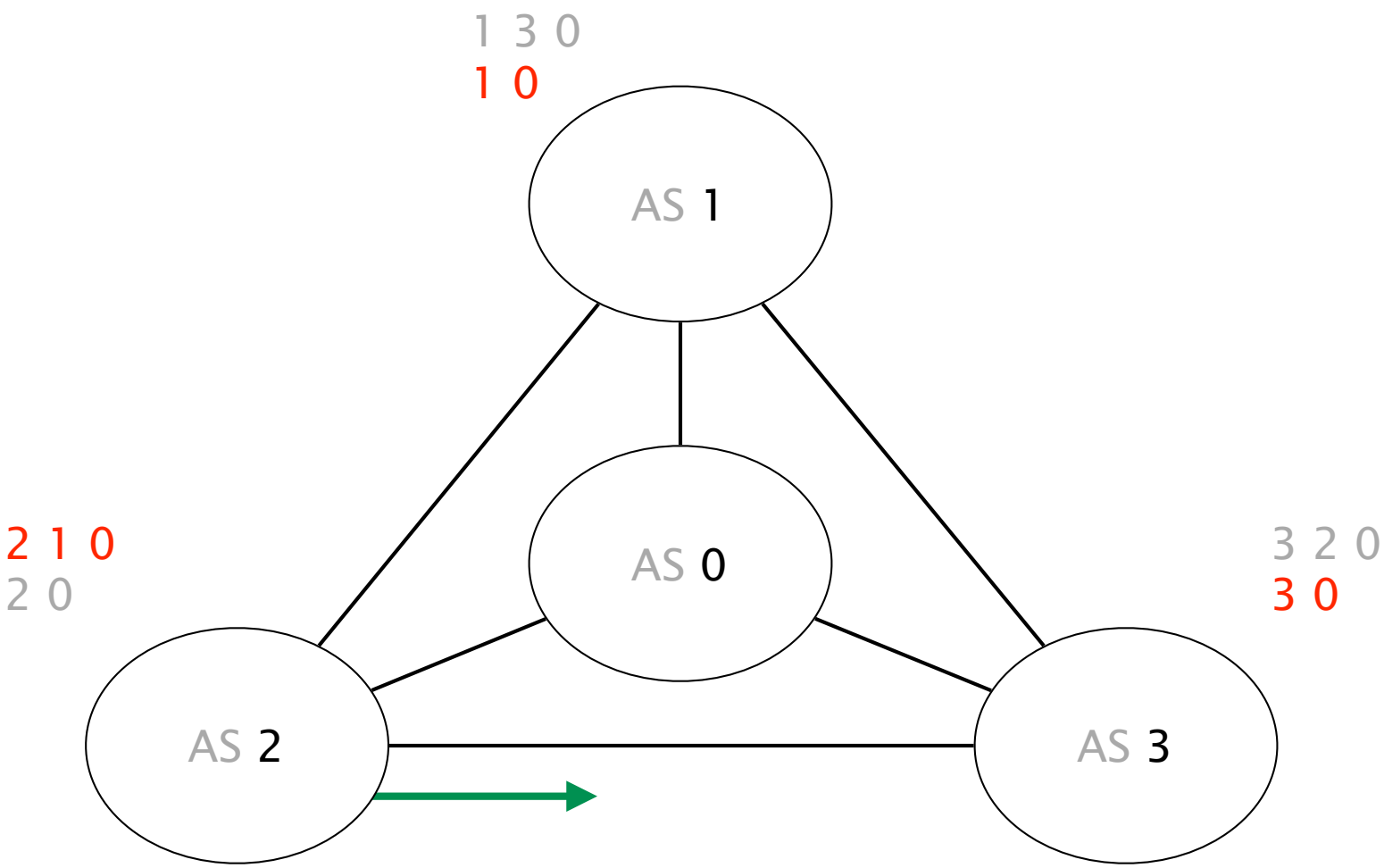


AS 2 advertises its new path 2 1 0 to AS 3

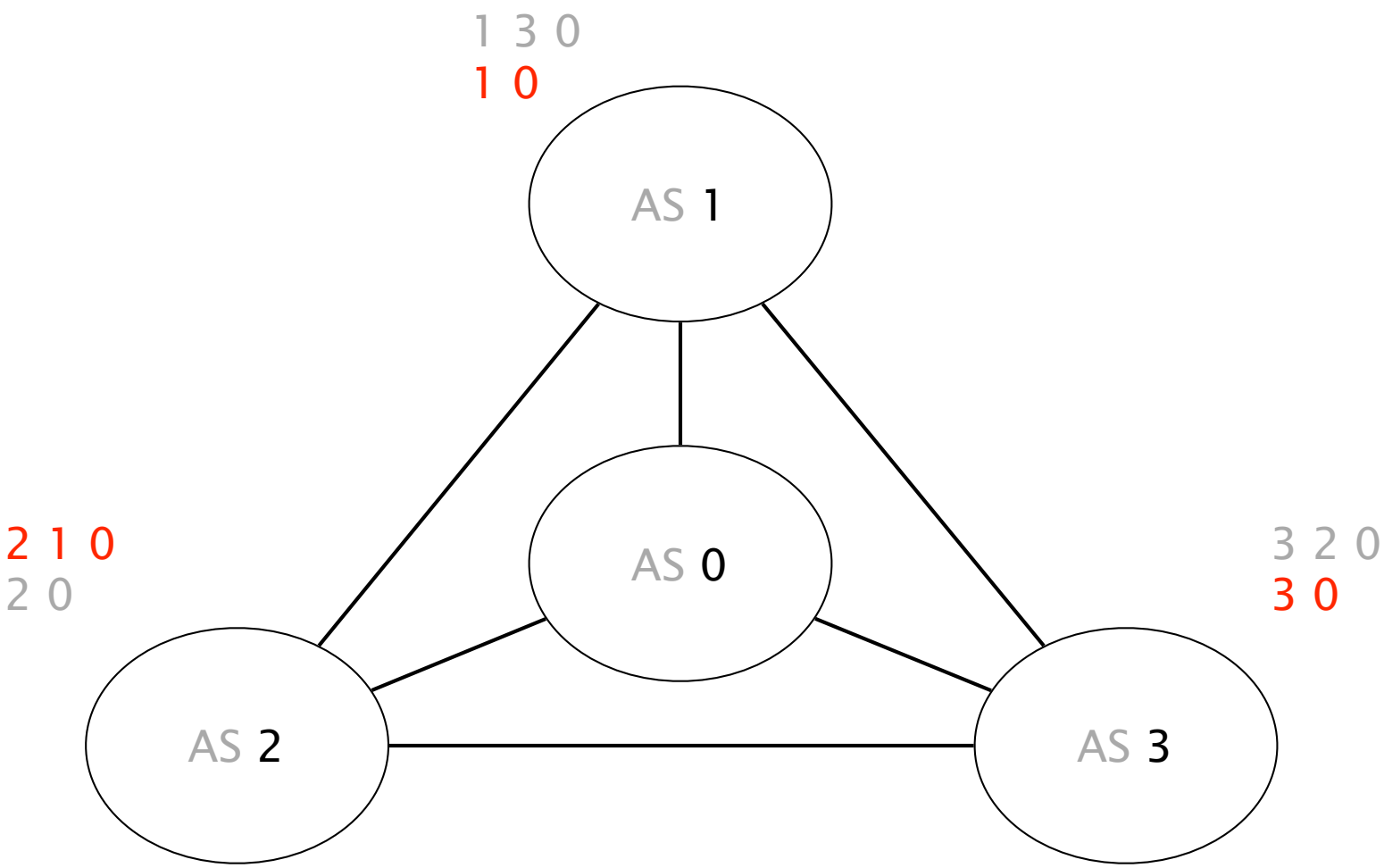


Upon reception,

AS 3 switches to its initial path 3 0



We are back where we started, from there on, the oscillation will continue forever



Policy oscillations are a direct consequence of policy autonomy

ASes are free to chose and advertise any paths they want

network stability argues against this

Guaranteeing the absence of oscillations is hard

even when you know all the policies!

In practice though,

BGP does not oscillate “that” often

known as “Gao-Rexford” rules

Theorem

If all AS policies follow the cust/peer/provider rules,
BGP is guaranteed to converge

Intuition

Oscillations require “preferences cycles”
which make no economical sense

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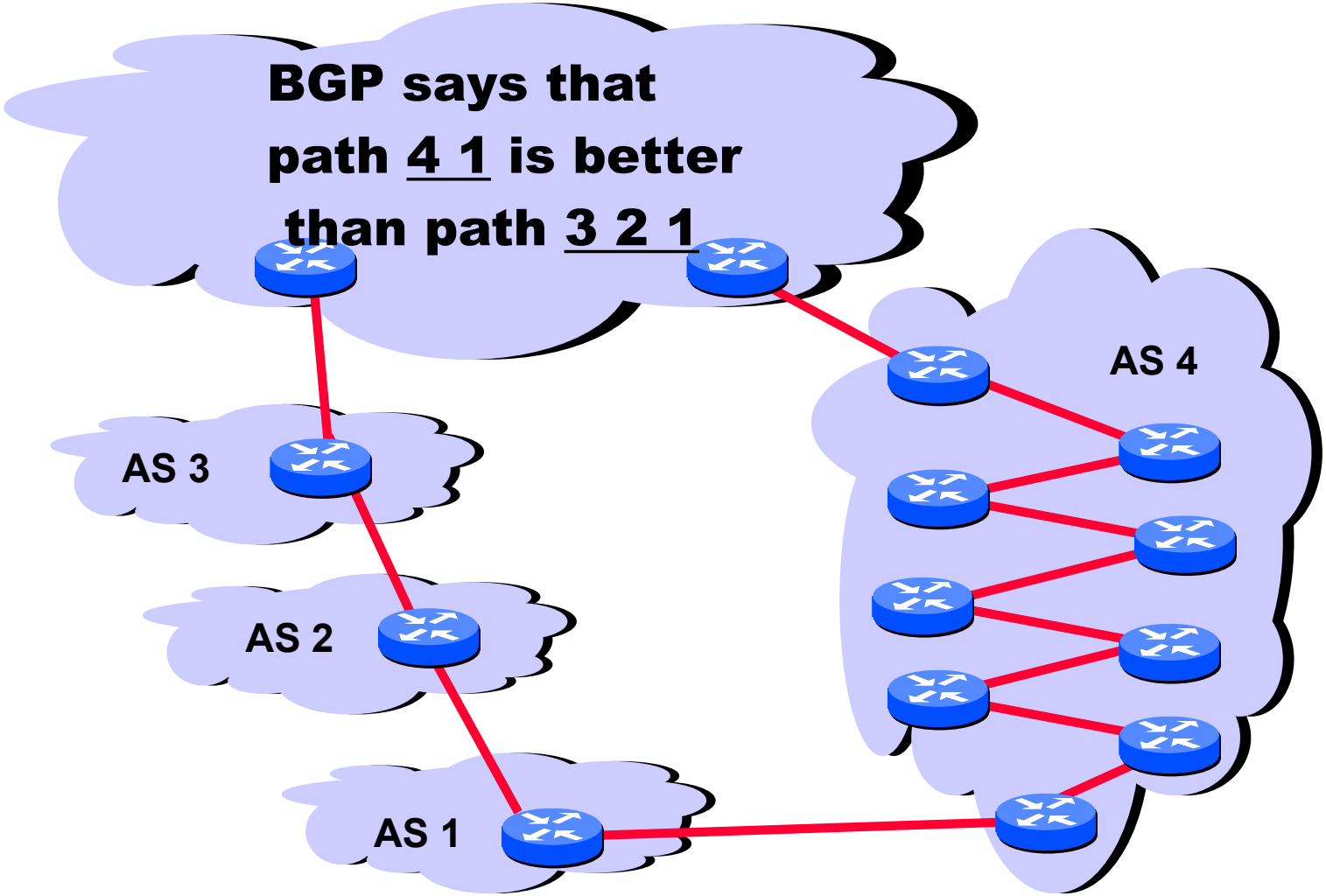
BGP path selection is mostly economical,
not based on accurate performance criteria



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BGP configuration is hard to get right

BGP is both “bloated” and underspecified

lots of knobs and (sometimes, conflicting) interpretations

BGP is often manually configured

humans make mistakes, often

BGP abstraction is fundamentally flawed

disjoint, router-based configuration to effect AS-wide policy

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The world of BGP policies is rapidly changing

ISPs are now eyeballs talking to content networks

e.g., Swisscom and Netflix/Spotify/YouTube

Transit becomes less important and less profitable

traffic move more and more to interconnection points

No systematic practices, yet

details of peering arrangements are private anyway

Border Gateway Protocol

policies and more

BGP Policies

Follow the Money

Protocol

How does it work?

Problems

security, performance, …

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Materials inspired from Scott Shenker & Jennifer Rexford