Communication Networks

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Communication Networks

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ETH Zürich (D-ITET)

April 1 2019

Materials inspired from Scott Shenker & Jennifer Rexford

Internet Hackathon

This Thursday @6pm in ETZ hall + ETZ E6

2016 edition

No exercise session this Thursday

Q&A session today (April 1)

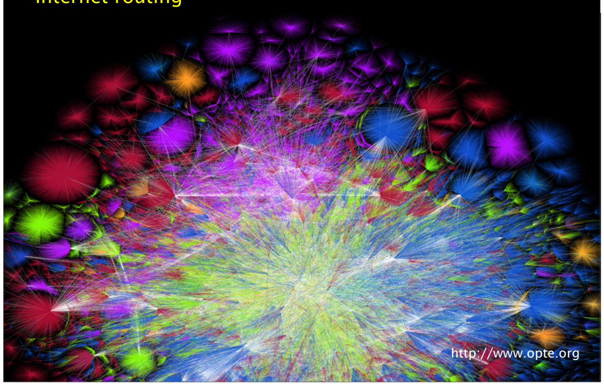
3pm to 5pm in ETZ G71.2

and online on #routing_project

Last week on

Communication Networks

Internet routing



Internet routing

from here to there, and back

1 Intra-domain routing

Link-state protocols

Distance-vector protocols

2 Inter-domain routing

Path-vector protocols

Internet routing
from here to there, and back

1 Intra-domain routing

Link-state protocols
Distance-vector protocols

Inter-domain routing

Path-vector protocols

In Link-State routing, routers build a precise map of the network by flooding local views to everyone

Each router keeps track of its incident links and cost
as well as whether it is up or down

Each router broadcast its own links state
to give every router a complete view of the graph

Routers run Dijkstra on the corresponding graph
to compute their shortest-paths and forwarding tables

Distance-vector protocols are based on Bellman-Ford algorithm

---

Let $d_x(y)$ be the cost of the least-cost path known by x to reach y

Each node bundles these distances into one message (called a vector) that it repeatedly sends to all its neighbors — until convergence

Each node updates its distances based on neighbors' vectors:

$d_x(y) = \min\{ c(x,v) + d_v(y) \}$ over all neighbors v

Internet routing
from here to there, and back

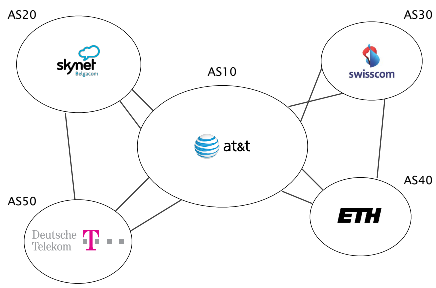
Intra-domain routing

Link-state protocols
Distance-vector protocols

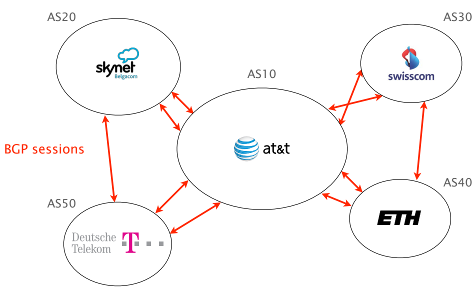
2 Inter-domain routing

Path-vector protocols

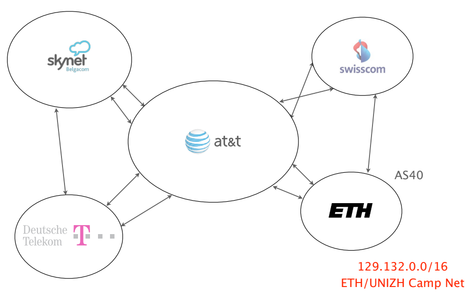
The Internet is a network of networks, referred to as Autonomous Systems (AS)



BGP is the routing protocol "glueing" the Internet together



Using BGP, ASes exchange information about the IP prefixes they can reach, directly or indirectly



BGP needs to solve three key challenges:
scalability, privacy and **policy enforcement**

There is a huge # of networks and prefixes
700k prefixes, >50,000 networks, millions (!) of routers

Networks don't want to divulge internal topologies
or their business relationships

Networks needs to control where to send and receive traffic
without an Internet-wide notion of a link cost metric

Link-State routing does not solve
these challenges

Floods topology information
high processing overhead

Requires each node to compute the entire path
high processing overhead

Minimizes some notion of total distance
works only if the policy is shared and uniform

Distance-Vector routing is on the right track

pros — Hide details of the network topology
nodes determine only "next-hop" for each destination

Distance-Vector routing is on the right track,
but not really there yet…

pros — Hide details of the network topology
nodes determine only "next-hop" for each destination

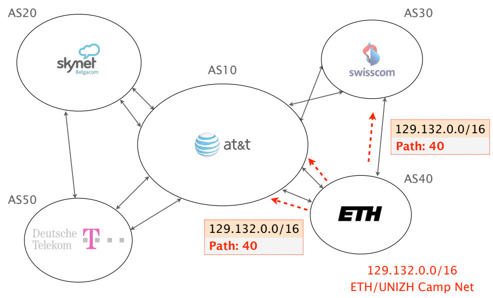
cons — It still minimizes some common distance
impossible to achieve in an inter domain setting

It converges slowly
counting-to-infinity problem

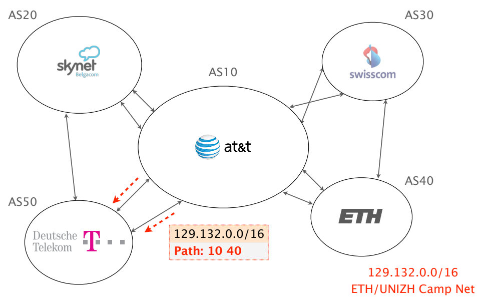
BGP relies on path-vector routing to support
flexible routing policies and avoid count-to-infinity

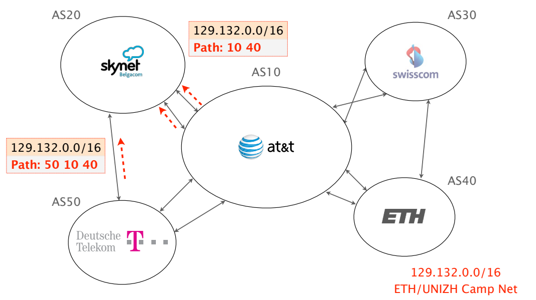
key idea — advertise the entire path instead of distances

BGP announcements carry complete path information
instead of distances



Each AS appends itself to the path
when it propagates announcements





This week on

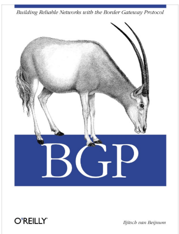
Communication Networks

Border Gateway Protocol

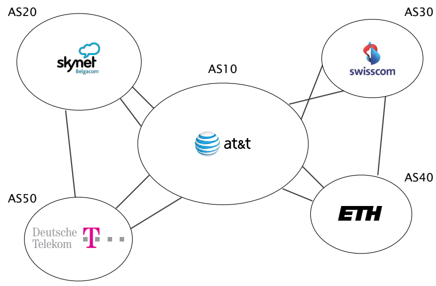
policies and more

Border Gateway Protocol

policies and more



The Internet topology is shaped according to business relationships



Intuition

2 ASes connect only if they have a business relationship

BGP is a "follow the money" protocol

There are 2 main business relationships today:

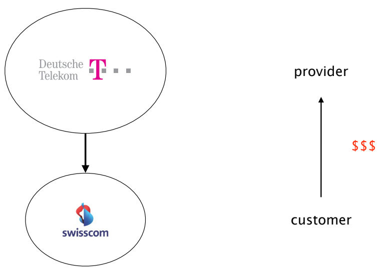
- customer/provider
- peer/peer

many less important ones (siblings, backups,…)

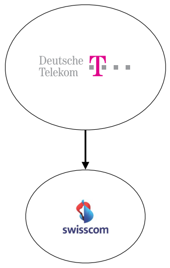
There are 2 main business relationships today:

- customer/provider
- peer/peer

Customers pay providers to get Internet connectivity



The amount paid is based on peak usage, usually according to the 95th percentile rule



Every 5 minutes, DT
records the # of bytes sent/received

At the end of the month, DT

- sorts all values in decreasing order
- removes the top 5% values
- bills wrt highest remaining value

Most ISPs discounts traffic unit price when pre-committing to certain volume

commit		unit price ($)	Minimum monthly bill ($/month)
10	Mbps	12	120
100	Mbps	5	500
1	Gbps	3.50	3,500
10	Gbps	1.20	12,000
100	Gbps	0.70	70,000

Examples taken from The 2014 Internet Peering Playbook

Internet Transit Prices have been continuously declining during the last 20 years

Internet Transit Pricing (1998-2015)
Source: http://DrPeering.net

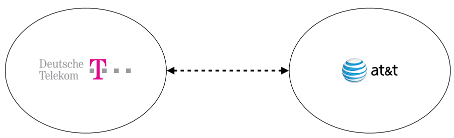
Year	Internet Transit Price		% decline
1998	$1,200.00	per Mbps	
1999	$800.00	per Mbps	33%
2000	$675.00	per Mbps	16%
2001	$400.00	per Mbps	41%
2002	$200.00	per Mbps	50%
2003	$120.00	per Mbps	40%
2004	$90.00	per Mbps	25%
2005	$75.00	per Mbps	17%
2006	$50.00	per Mbps	33%
2007	$25.00	per Mbps	50%
2008	$12.00	per Mbps	52%
2009	$9.00	per Mbps	25%
2010	$5.00	per Mbps	44%
2011	$3.25	per Mbps	35%
2012	$2.34	per Mbps	28%
2013	$1.57	per Mbps	33%
2014	$0.94	per Mbps	40%
2015	$0.63	per Mbps	33%

The reason? Internet commoditization & competition

There are 2 main business relationships today:

- customer/provider
- peer/peer

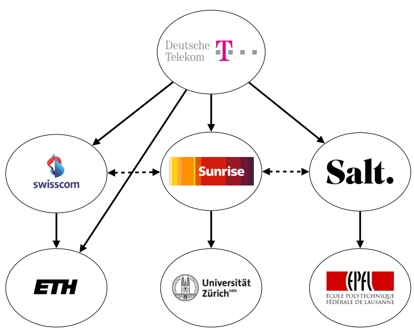
Peers don't pay each other for connectivity, they do it *out of common interest*

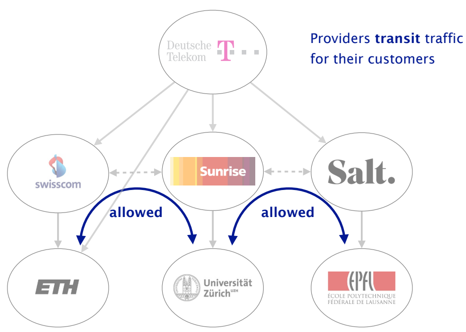


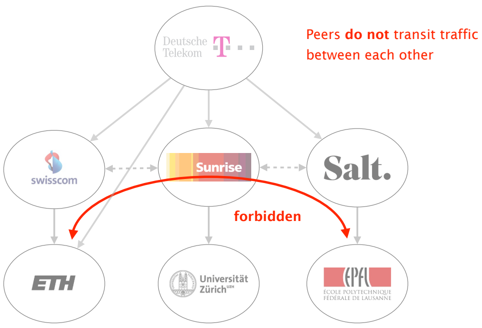
peer　　peer

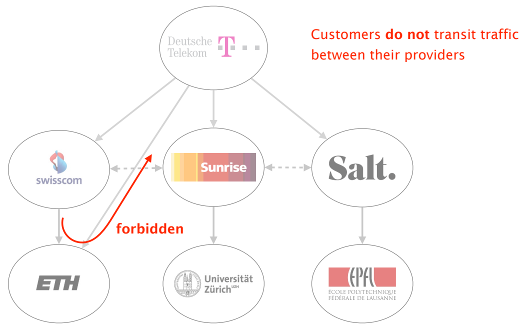
DT and ATT exchange *tons* of traffic.
they save money by directly connecting to each other

To understand Internet routing, follow the money





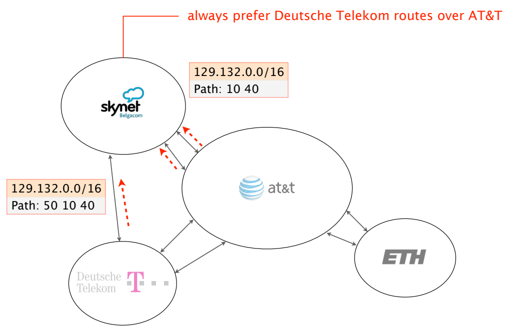


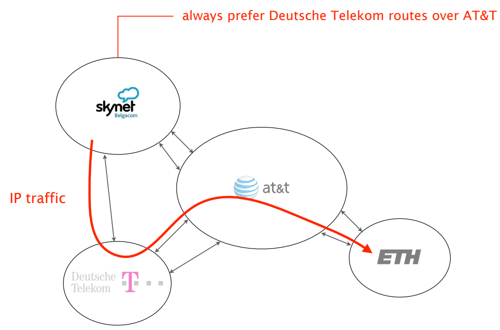


These policies are defined by constraining which BGP routes are *selected* and *exported*

Selection	Export
which path to use?	which path to advertise?

Selection	Export
which path to use? control outbound traffic	which path to advertise?





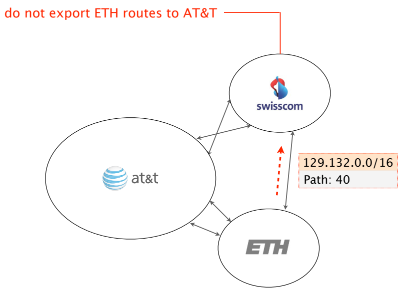
Business relationships conditions
route selection

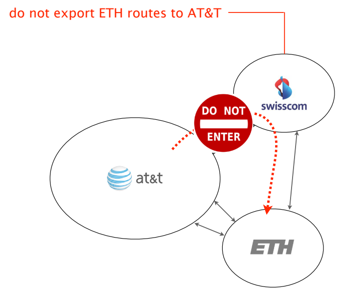
For a destination *p*, prefer routes coming from

- customers over
- peers over
- providers

route type

Selection	Export
which path to use?	which path to advertise? control inbound traffic





Business relationships conditions
route exportation

		send to		
		customer	peer	provider
	customer			
from	peer			
	provider			

Routes coming from customers
are propagated to everyone else

		send to		
		customer	peer	provider
	customer	✓	✓	✓
from	peer			
	provider			

Routes coming from peers and providers
are only propagated to customers

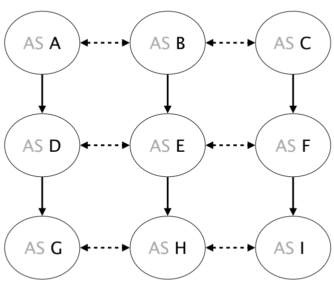
		send to		
		customer	peer	provider
	customer	✓	✓	✓
from	peer	✓	-	-
	provider	✓	-	-

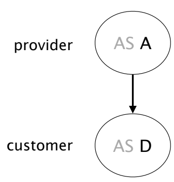
Selection

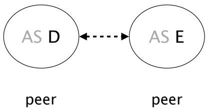
which path to use?
control outbound traffic

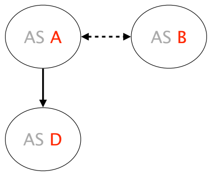
Export

which path to advertise?
control inbound traffic

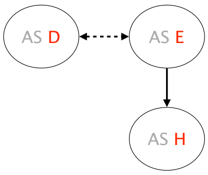




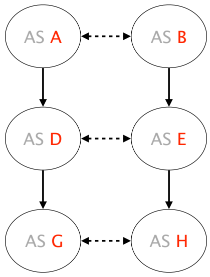




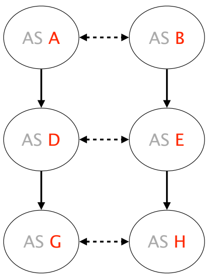
Is (B, A, D) a valid path? Yes/No



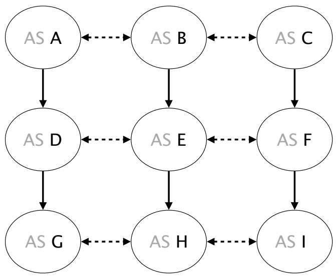
Is (H, E, D) a valid path? Yes/No



Is (G,D,A,B,E,H) a valid path? Yes/No



Will (G,D,A,B,E,H) actually see packets? Yes/No



What's a valid path between G and I?

Border Gateway Protocol

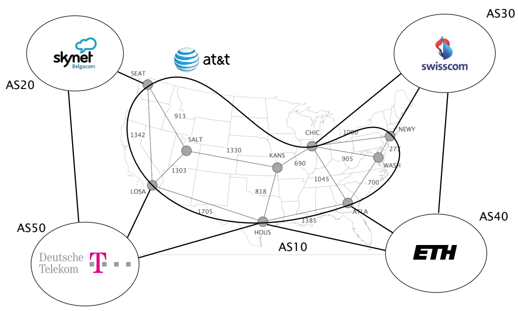
policies and more

BGP Policies
Follow the Money

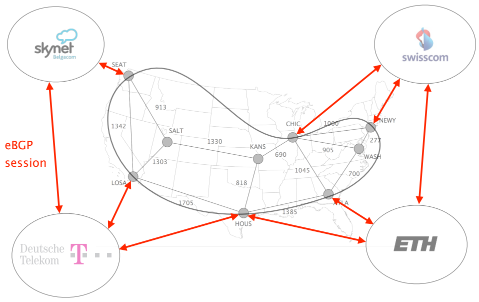
2 Protocol
How does it work?

Problems
security, performance, …

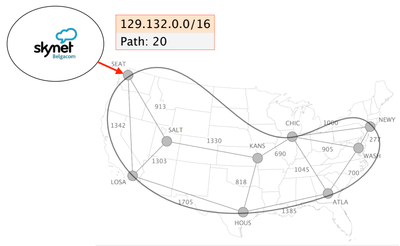
BGP sessions come in two flavors



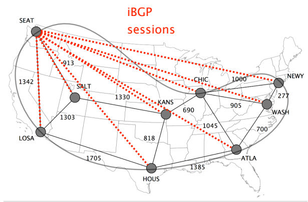
external BGP (eBGP) sessions
connect border routers in different ASes



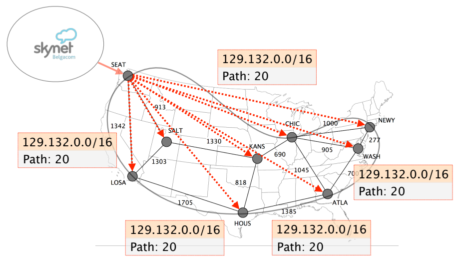
eBGP sessions are used to learn routes to
external destinations

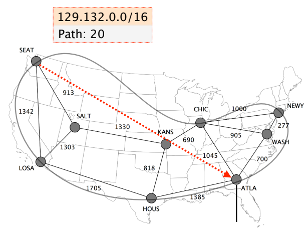


internal BGP (iBGP) sessions connect
the routers in the same AS



iBGP sessions are used to disseminate
externally-learned routes internally

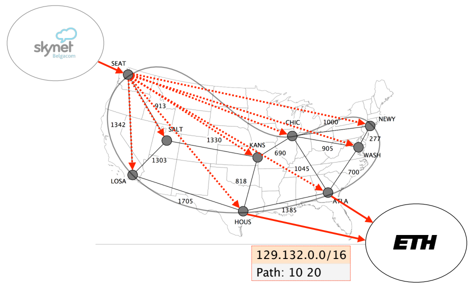




I can reach "129.132/16" via SEAT,
internal NH is CHIC

learned via IGP (*e.g.*, OSPF)

Routes disseminated internally are then announced
externally again, using eBGP sessions



On the wire, BGP is a rather simple protocol
composed of four basic messages

type	used to...
OPEN	establish TCP-based BGP sessions
NOTIFICATION	report unusual conditions
UPDATE	inform neighbor of a new best route a change in the best route the removal of the best route
KEEPALIVE	inform neighbor that the connection is alive

UPDATE	inform neighbor of a new best route a change in the best route the removal of the best route

BGP UPDATEs carry an IP prefix
together with a set of attributes

IP prefix

Attributes

BGP UPDATEs carry an IP prefix
together with a set of attributes

IP prefix

Attributes — Describe route properties

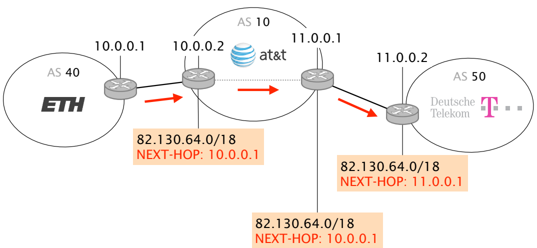
used in route selection/exportation decisions

are either local (*only* seen on iBGP)
or global (seen on iBGP *and* eBGP)

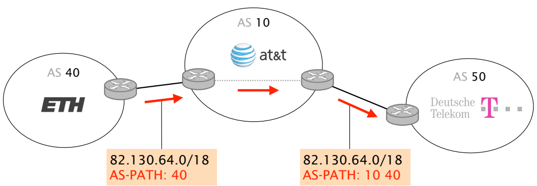
Attributes	Usage
NEXT-HOP	egress point identification
AS-PATH	loop avoidance outbound traffic control inbound traffic control
LOCAL-PREF	outbound traffic control
MED	inbound traffic control

The NEXT-HOP is a global attribute which
indicates where to send the traffic next

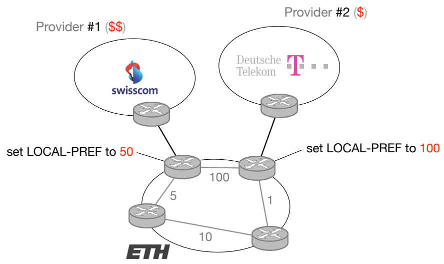
The NEXT-HOP is set when the route enters an AS,
it does not change within the AS



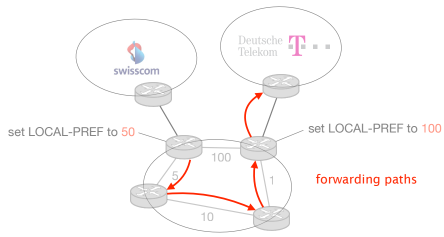
The AS-PATH is a global attribute that lists
all the ASes a route has traversed (in reverse order)



The LOCAL-PREF is a *local* attribute set at the border,
it represents how "preferred" a route is

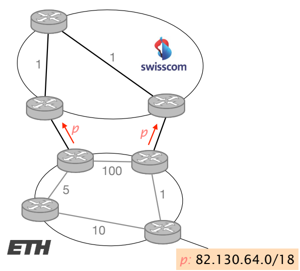


By setting a higher LOCAL-PREF,
all routers end up using DT to reach any external prefixes,
even if they are closer (IGP-wise) to the Swisscom egress

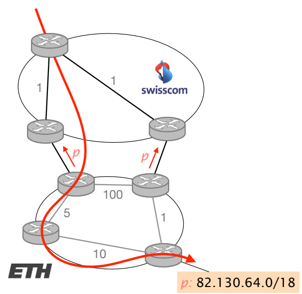


The MED is a *global* attribute which encodes
the relative "proximity" of a prefix wrt to the announcer

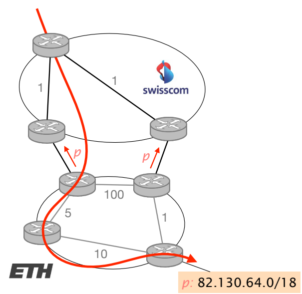
Swisscom receives two routes to reach *p*



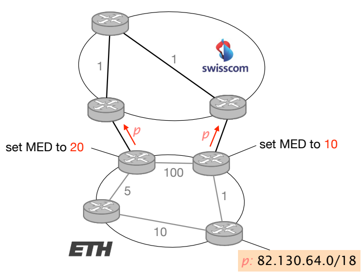
Swisscom receives two routes to reach *p*
and chooses (arbitrarily) its left router as egress



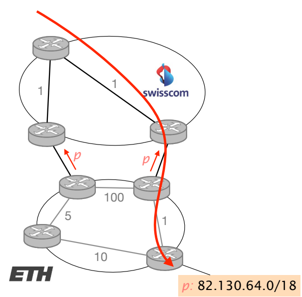
Yet, ETH would prefer to receive traffic for *p*
on its right border router which is closer to the actual destination



ETH can communicate that preferences to Swisscom
by setting a higher MED on *p* when announced from the left



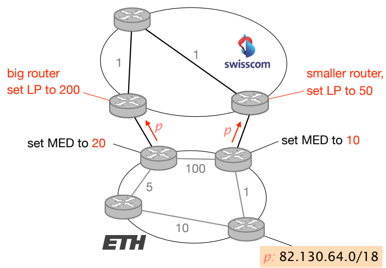
Swisscom receives two routes to reach *p*
and, *given it does not cost it anything more*,
chooses its right router as egress



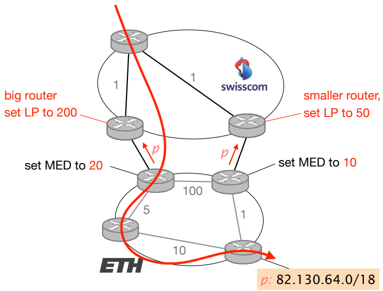
Swisscom receives two routes to reach *p*
and, *given it does not cost it anything more,*
chooses its right router as egress

But what if it does?

Consider that Swisscom always prefer to send traffic
via its left egress point (bigger router, less costly)



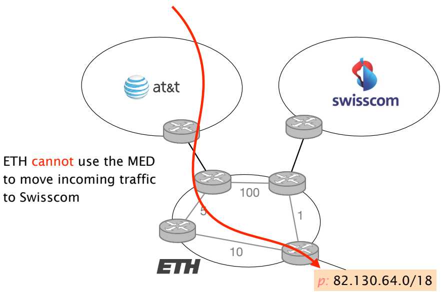
In this case, Swisscom will not care about the MED value
and still push the traffic via its left router



Lesson — The network which is sending the traffic always has the final word when it comes to deciding where to forward

Corollary — The network which is receiving the traffic can just influence remote decision, not control them

With the MED, an AS can influence its inbound traffic
between multiple connection towards the same AS



BGP UPDATEs carry an IP prefix
together with a set of attributes

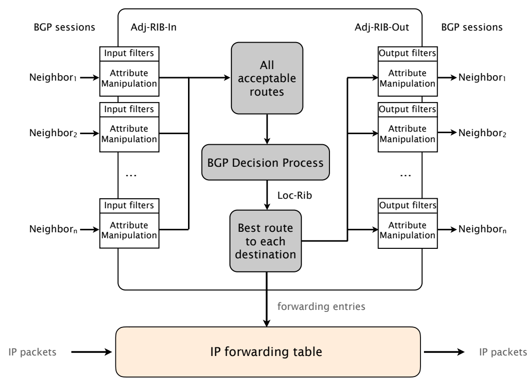
IP prefix

Attributes — Describe route properties

used in route selection/exportation decisions

are either local (*only* seen on iBGP)
or global (seen on iBGP *and* eBGP)

Each BGP router processes UPDATEs according to
a precise pipeline



Given the set of all acceptable routes for each prefix, the BGP Decision process elects a single route

BGP is often referred to as
a single path protocol

Prefer routes…

with higher LOCAL-PREF

with shorter AS-PATH length

with lower MED

learned via eBGP instead of iBGP

with lower IGP metric to the next-hop

with smaller egress IP address (tie-break)

learned via eBGP instead of iBGP

with lower IGP metric to the next-hop

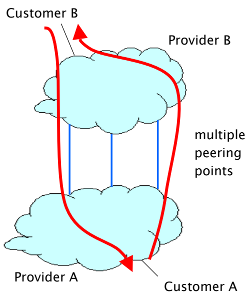
These two steps aim at directing traffic
as quickly as possible out of the AS (early exit routing)

ASes are selfish

They dump traffic
as soon as possible
to someone else

This leads to asymmetric routing

Traffic does not flow on
the same path
in both directions



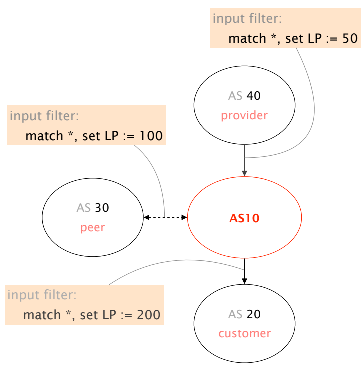
Let's look at how operators implement
customer/provider and peer policies in practice

To implement their selection policy, operators define input filters which manipulates the LOCAL-PREF

For a destination *p*, prefer routes coming from

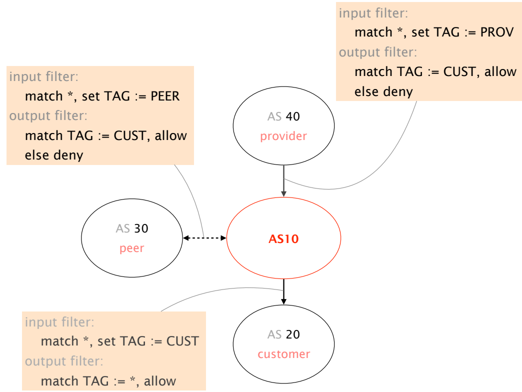
- customers over
- peers over
- providers

route type



To implement their exportation rules,
operators use a mix of import and export filters

		send to		
		customer	peer	provider
	customer	✓	✓	✓
from	peer	✓	-	-
	provider	✓	-	-



Border Gateway Protocol
policies and more

BGP Policies
Follow the Money

Protocol
How does it work?

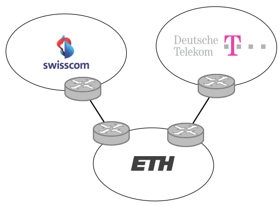
3 Problems
security, performance, ...

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
simply absent from BGP specifications

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

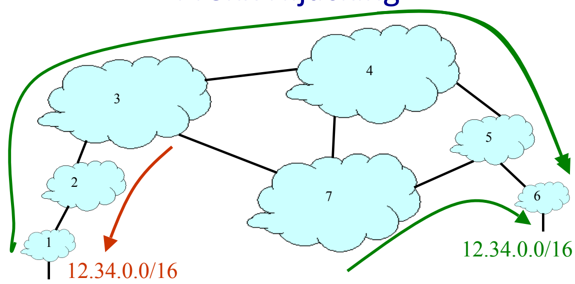
#1 BGP does not validate the origin of advertisements

#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

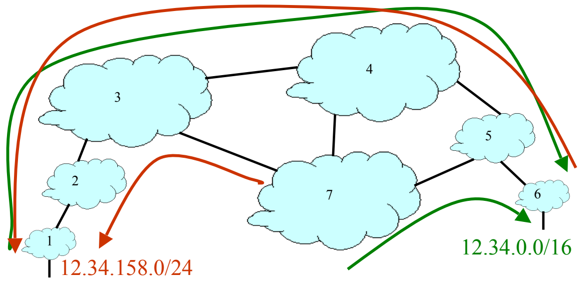


- Blackhole: data traffic is discarded
- Snooping: data traffic is inspected, then redirected
- Impersonation: traffic sent to bogus destinations

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

YouTube Outage on Feb 24, 2008

- YouTube (AS 36561)
  - Web site www.youtube.com (208.65.152.0/22)
- Pakistan Telecom (AS 17557)
  - Government order to block access to YouTube
  - Announces 208.65.153.0/24 to PCCW (AS 3491)
  - All packets to YouTube get dropped on the floor
- Mistakes were made
  - AS 17557: announce to everyone, not just customers
  - AS 3491: not filtering routes announced by AS 17557
- Lasted 100 minutes for some, 2 hours for others

Timeline (UTC Time)

- 18:47:45
  - First evidence of hijacked /24 route in Asia
- 18:48:00
  - Several big trans-Pacific providers carrying the route
- 18:49:30
  - Bogus route fully propagated
- 20:07:25
  - YouTube starts advertising /24 to attract traffic back
- 20:08:30
  - Many (but not all) providers are using valid route

Timeline (UTC Time)

- 20:18:43
  - YouTube announces two more-specific /25 routes
- 20:19:37
  - Some more providers start using the /25 routes
- 20:50:59
  - AS 17557 starts prepending ("3491 17557 17557")
- 20:59:39
  - AS 3491 disconnects AS 17557
- 21:00:00
  - Videos of cats flushing toilets are available again!

Another Example: Spammers

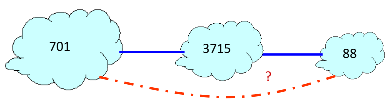
- Spammers sending spam
  - Form a (bidirectional) TCP connection to mail server
  - Send a bunch of spam e-mail, then disconnect
- But, best not to use your real IP address
  - Relatively easy to trace back to you
- Could hijack someone's address space
  - But you might not receive all the (TCP) return traffic
- How to evade detection
  - Hijack unused (i.e., unallocated) address block
  - Temporarily use the IP addresses to send your spam

BGP (lack of) security

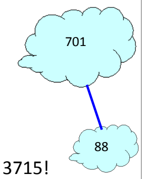
#1	BGP does not validate the origin of advertisements
#2	BGP does not validate the content of advertisements

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



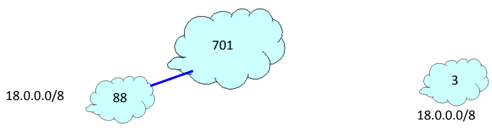
Bogus AS Paths



- 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?

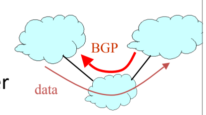
Bogus AS Paths

- 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



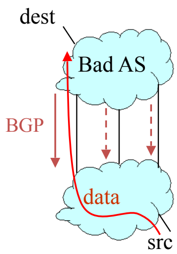
Invalid Paths

- 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

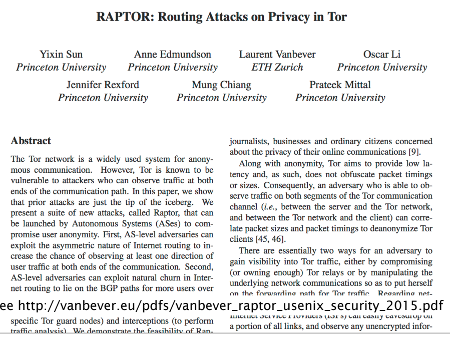
- Peers require consistent export
  - Prefix advertised at all peering points
  - Prefix advertised with same AS path length
- Reasons for violating the policy
  - Trick neighbor into "cold potato"
  - Configuration mistake
- Main defense
  - Analyzing BGP updates, or traffic,
  - … for signs of inconsistency



BGP Security Today

- Applying best common practices (BCPs)
  - Securing the session (authentication, encryption)
  - Filtering routes by prefix and AS path
  - Packet filters to block unexpected control traffic
- This is not good enough
  - Depends on vigilant application of BCPs
  - Doesn't address fundamental problems
    - Can't tell who owns the IP address block
    - Can't tell if the AS path is bogus or invalid
    - Can't be sure the data packets follow the chosen route

Routing attacks can be used to
de-anonymize Tor users

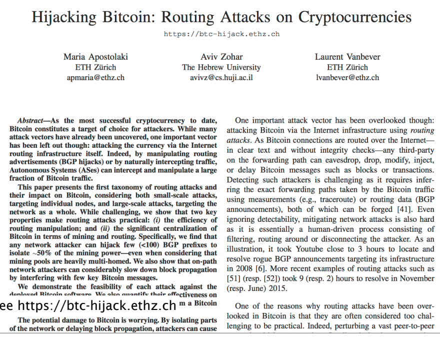

RAPTOR: Routing Attacks on Privacy in Tor

Yixin Sun, Princeton University; Anne Edmundson, Princeton University; Laurent Vanbever, ETH Zurich; Oscar Li, Princeton University; Jennifer Rexford, Princeton University; Mung Chiang, Princeton University; Prateek Mittal, Princeton University

Abstract

See http://vanbever.eu/pdfs/vanbever_raptor_usenix_security_2015.pdf

Routing attacks can be used to
partition the Bitcoin network


Hijacking Bitcoin: Routing Attacks on Cryptocurrencies

https://btc-hijack.ethz.ch

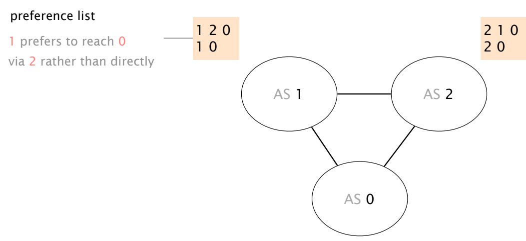
Maria Apostolaki, ETH Zürich, apmaria@ethz.ch; Aviv Zohar, The Hebrew University, avivz@cs.huji.ac.il; Laurent Vanbever, ETH Zürich, lvanbever@ethz.ch

See https://btc-hijack.ethz.ch

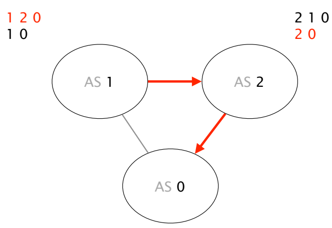
Problems

- Reachability
- Security
- Convergence
- Performance
- Anomalies
- Relevance

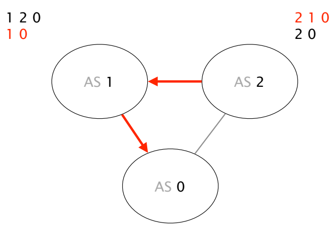
With arbitrary policies,
BGP may have multiple stable states



If AS2 is the first to advertise 2 0,
the system stabilizes in a state where AS 1 is happy



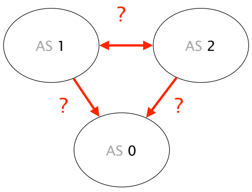
If AS1 is the first one to advertise 1 0,
the system stabilizes in a state where AS 2 is happy



The actual assignment depends on the ordering between the messages

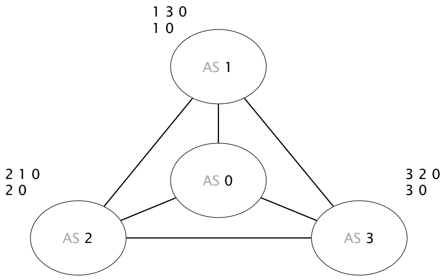
Note that AS1/AS2 could change the outcome by manual intervention

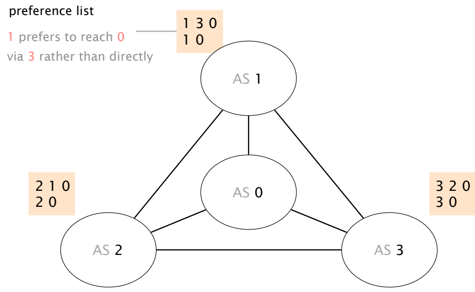
… this is not always possible *



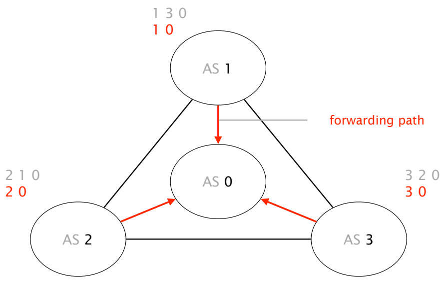
* https://www.nanog.org/meetings/nanog31/presentations/griffin.pdf

With arbitrary policies,
BGP may fail to converge

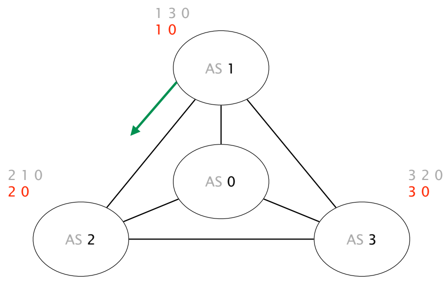




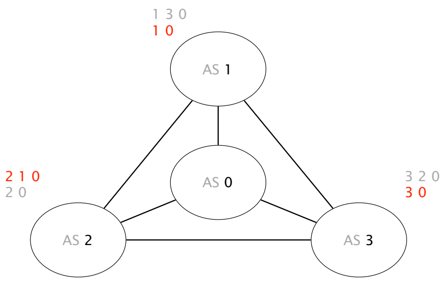
Initially, all ASes only know the direct route to 0



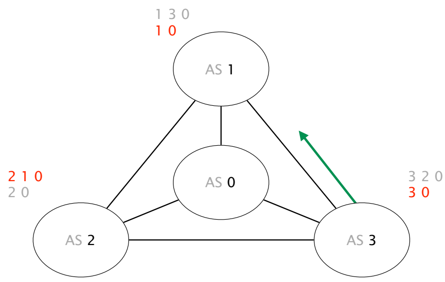
AS 1 advertises its path to AS 2



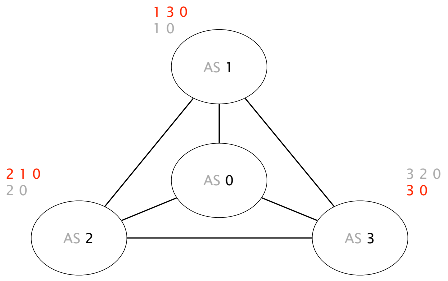
Upon reception,
AS 2 switches to 2 1 0 (preferred)



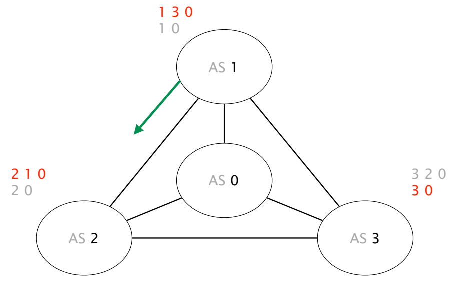
AS 3 advertises its path to AS 1



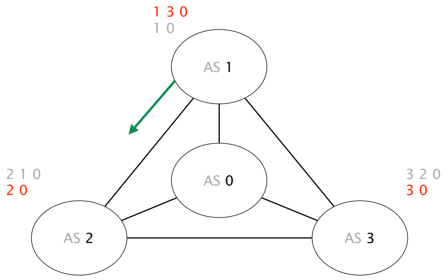
Upon reception,
AS 1 switches to 1 3 0 (preferred)



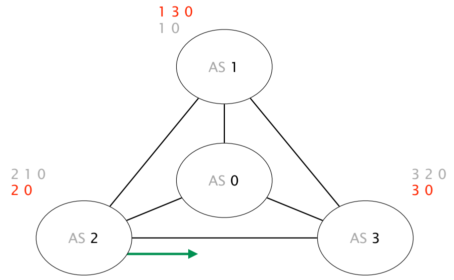
AS 1 advertises its new path 1 3 0 to AS 2



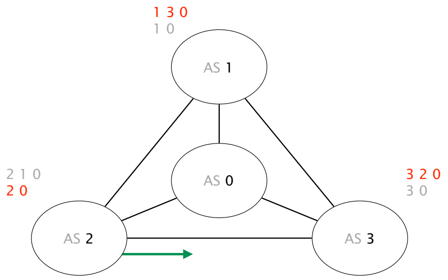
Upon reception,
AS 2 reverts back to its initial path 2 0



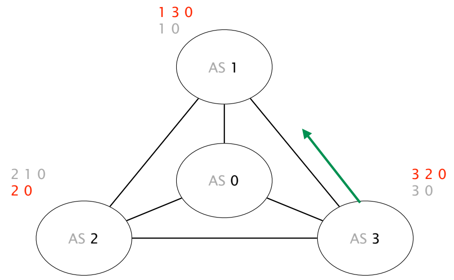
AS 2 advertises its path 2 0 to AS 3



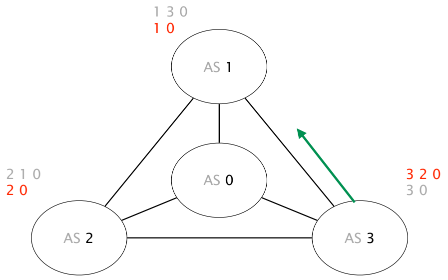
Upon reception,
AS 3 switches to 3 2 0 (preferred)



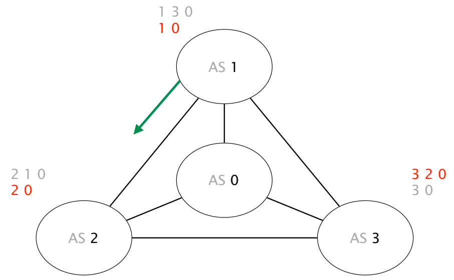
AS 3 advertises its new path 3 2 0 to AS 1



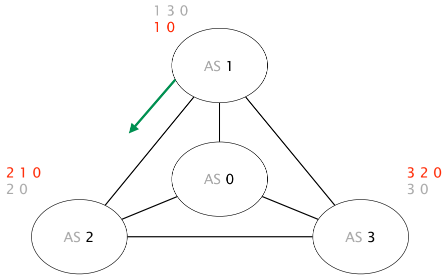
Upon reception,
AS 1 reverts back to 1 0 (initial path)



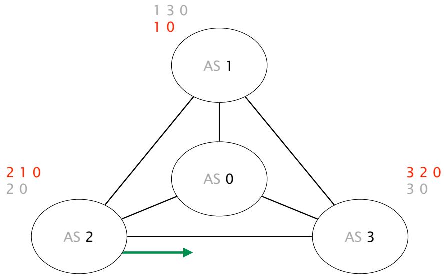
AS 1 advertises its new path 1 0 to AS 2



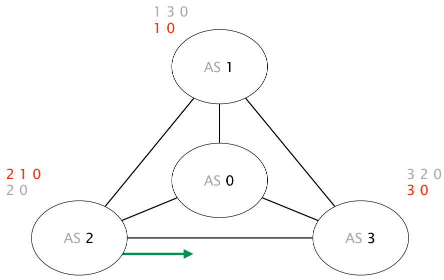
Upon reception,
AS 2 switches to 2 1 0 (preferred)



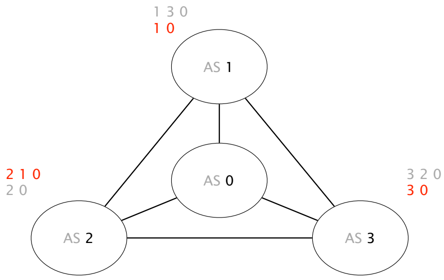
AS 2 advertises its new path 2 1 0 to AS 3



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!

Guaranteeing the absence of oscillations is hard

even when you know all the policies!

How come?

Theorem

Computationally, a BGP network is as "powerful" as

see "Using Routers to Build Logic Circuits: How Powerful is BGP?"

How do you prove such a thing?

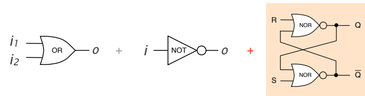
How do you prove such a thing?

Easy, you build a computer using BGP…

Logic gates

Logic gates

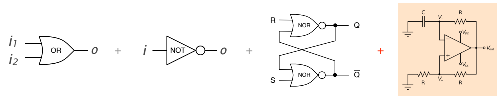
Memory



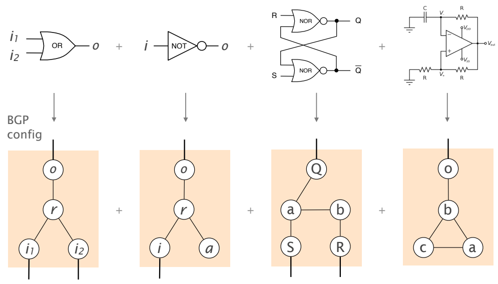
Logic gates

Memory

Clock



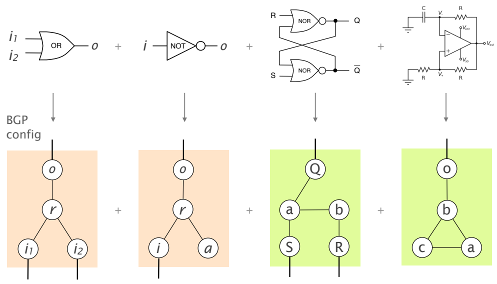
BGP has it all!



BGP has it all!

Memory

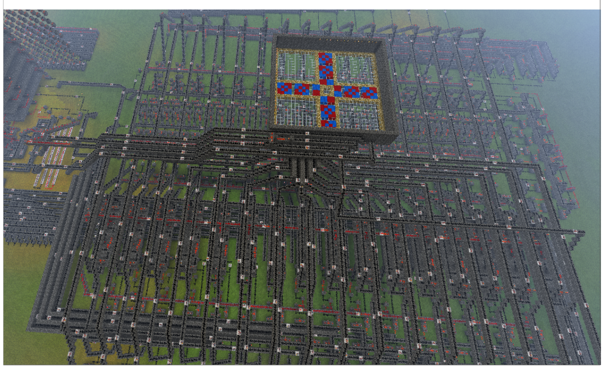
Clock



famous incorrect BGP configurations (Griffin et al.)

Instead of using Minecraft
for building a computer… use BGP!

Hack III, Minecraft's largest computer to date



Together, BGP routers form
the largest computer in the world!

Router-level view of the Internet, OPTE project

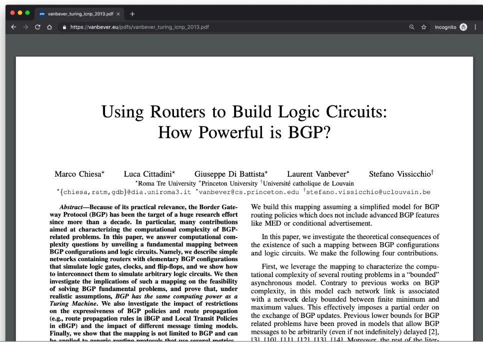
Checking BGP correctness is as hard as checking the termination of a general program

Theorem 1 — Determining whether a finite BGP network converges is PSPACE-hard

Theorem 2 — Determining whether an infinite BGP network converges is Turing-complete

Checking our paper for more details

https://vanbever.eu/pdfs/vanbever_turing_icnp_2013.pdf


Using Routers to Build Logic Circuits: How Powerful is BGP?

Marco Chiesa, Luca Cittadini, Giuseppe Di Battista, Laurent Vanbever, Stefano Vissicchio

In practice though, BGP does not oscillate "that" often

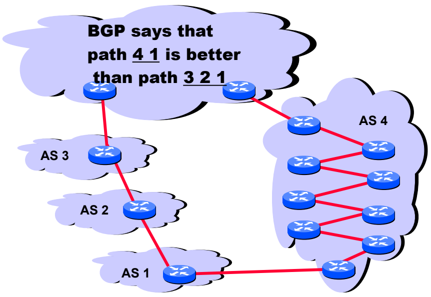
known as "Gao-Rexford" rules

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

Problems
- Reachability
- Security
- Convergence
- Performance
- Anomalies
- Relevance

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



Problems
- Reachability
- Security
- Convergence
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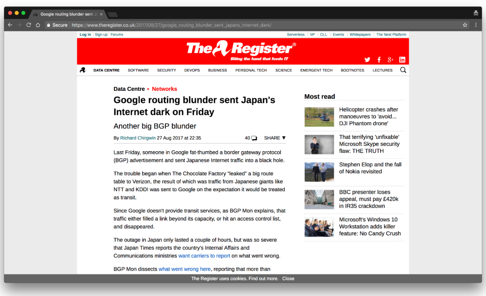
- Relevance

BGP configuration is hard to get right, you'll understand that very soon

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



https://www.theregister.co.uk/2017/08/27/google_routing_blunder_sent_japans_internet_dark/

In August 2017

Someone in Google fat-thumbed a
Border Gateway Protocol (BGP) advertisement
and sent Japanese Internet traffic into a black hole.

In August 2017

Someone in Google fat-thumbed a
Border Gateway Protocol (BGP) advertisement
and sent Japanese Internet traffic into a black hole.

[...] Traffic from Japanese giants like NTT and KDDI
was sent to Google on the expectation
it would be treated as transit.

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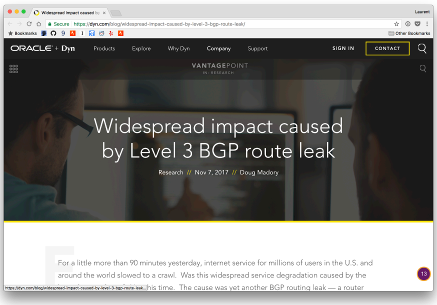
[...] Traffic from Japanese giants like NTT and KDDI
was sent to Google on the expectation
it would be treated as transit.

The outage in Japan only lasted a couple of hours
but was so severe that [...] the country's
Internal Affairs and Communications ministries
want carriers to report on what went wrong.

Another example,
this time from November 2017



https://dyn.com/blog/widespread-impact-caused-by-level-3-bgp-route-leak/

For a little more than 90 minutes [...],

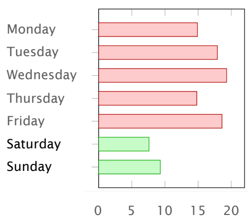
Internet service for millions of users in the U.S.
and around the world slowed to a crawl.

The cause was yet another BGP routing leak,
a router misconfiguration directing Internet traffic
from its intended path to somewhere else.

"Human factors are responsible
for 50% to 80% of network outages"

Juniper Networks, *What's Behind Network Downtime?*, 2008

Ironically, this means that the Internet works better
during the week-ends...



% of route leaks
source: Job Snijders (NTT)

Problems

- Reachability
- Security
- Convergence
- Performance
- Anomalies
- Relevance

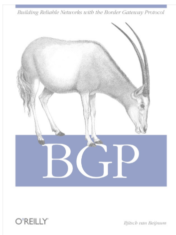
The world of BGP policies is rapidly changing

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, …