CSE508 Network Security

Stony Brook University

2021-02-23

Core Protocols: BGP

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IPv4 Addressing and Forwarding

Packets are routed based on their destination IP address

Router's task: for every IP address, forward the packet to the next hop

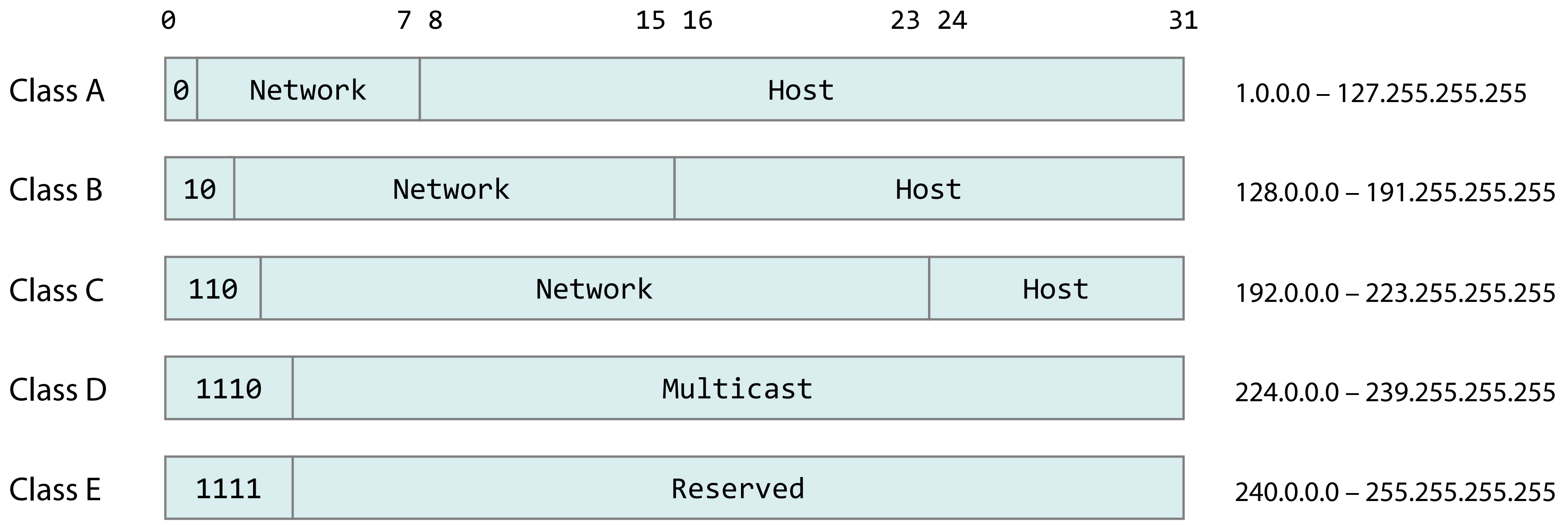
- Table lookup for each packet in a routing table

32-bit addresses, 2^{32} possibilities → impractical to maintain 2^{32} entries

- *Solution: hierarchical address scheme*

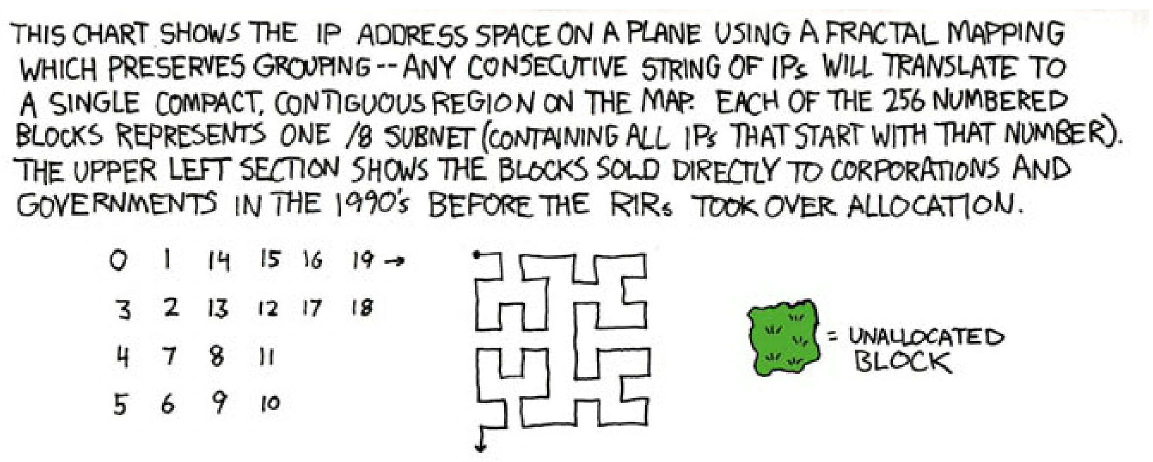
	0	31
IP address:	`Network Prefix`	`Host Identifier`
	Known by all routers	*Known by edge/internal (LAN) routers*

IPv4 Address Classes

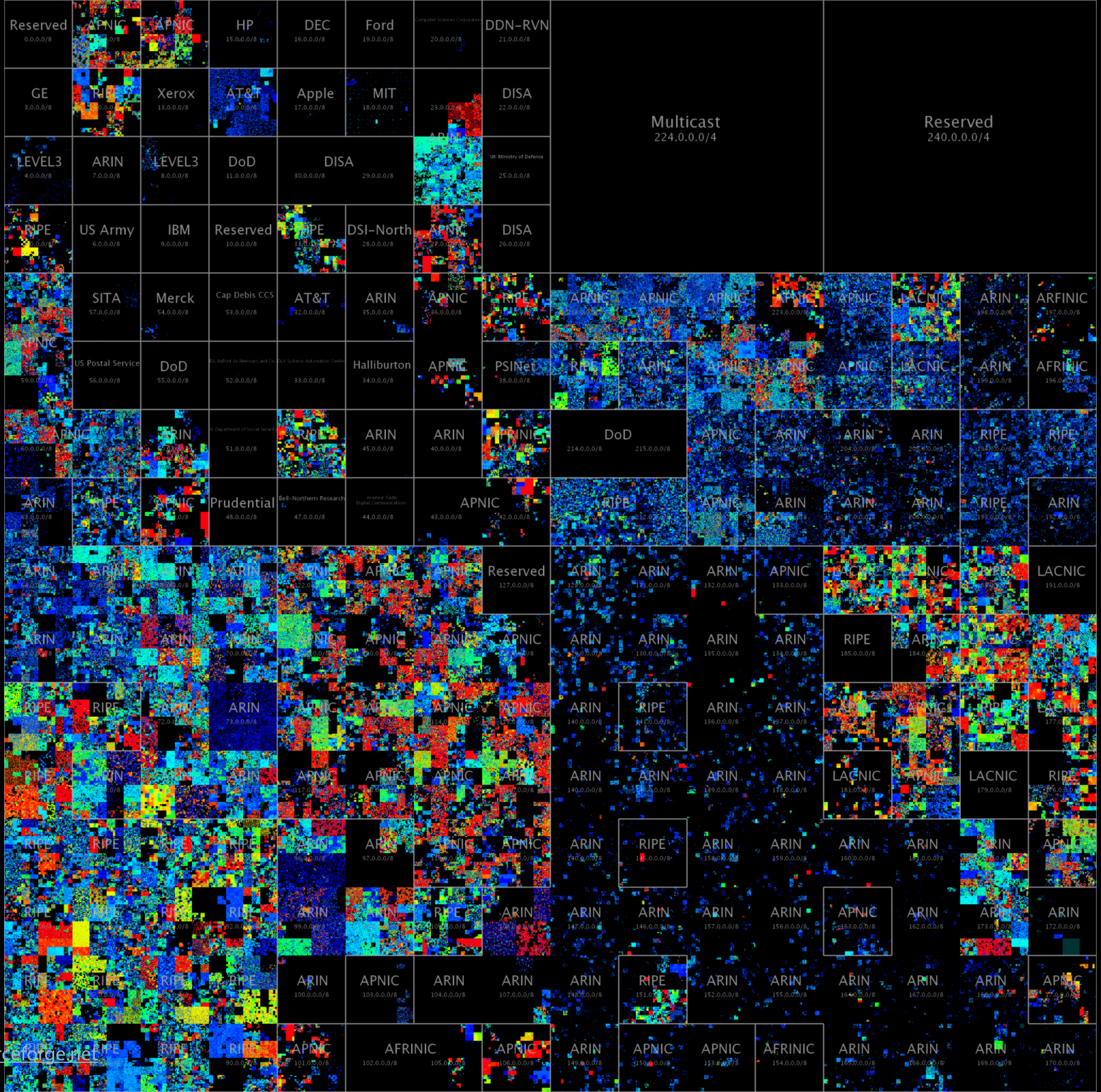


Classless Inter-Domain Routing (CIDR) was introduced in 1993

- Replaced the *classful* A/B/C network addressing architecture
- IP addresses are now associated with a *subnet mask*
- Allocations to ISPs and end users can be made on any address-bit boundary



No green patches after 2011…



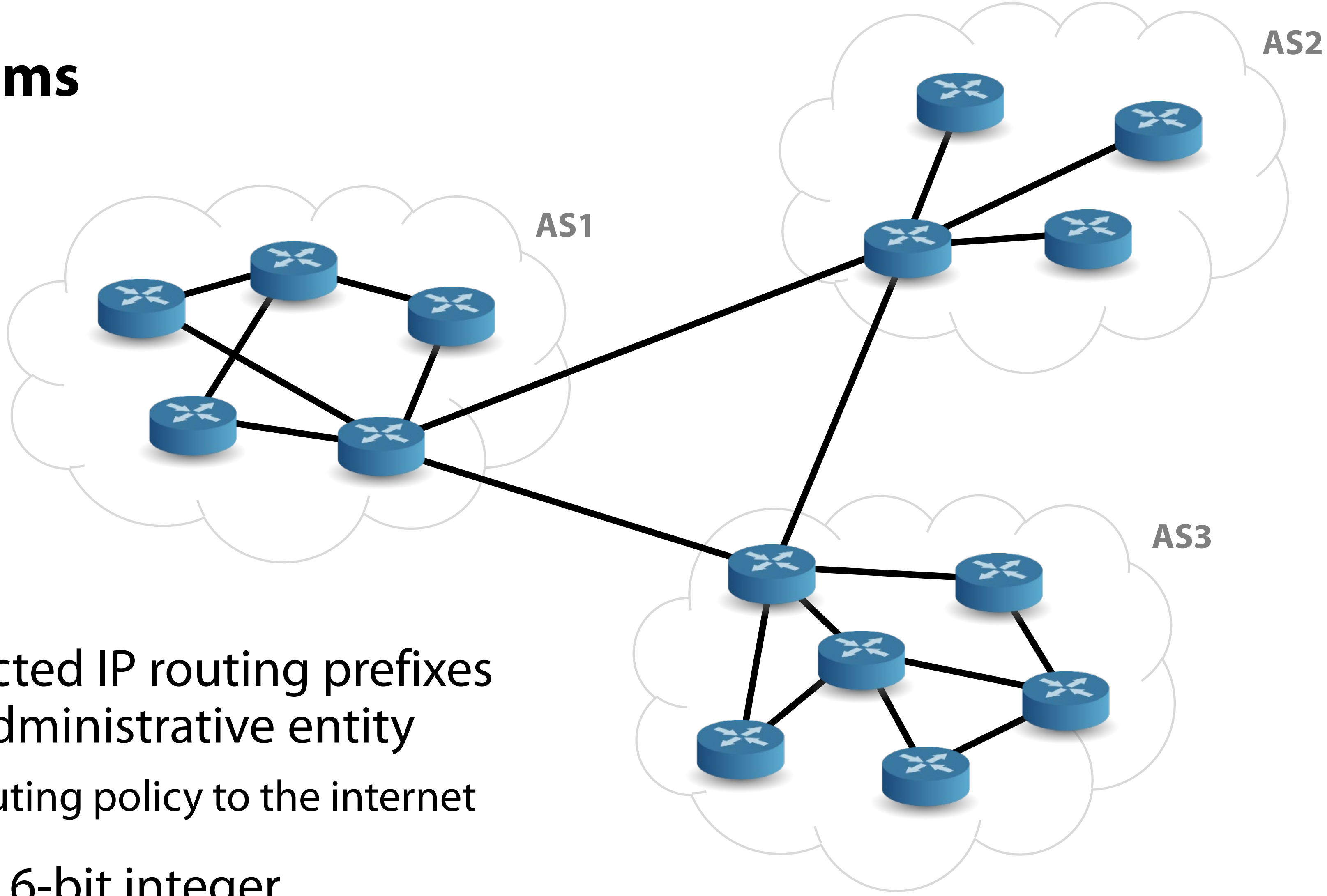
IPv4 Census Map

June – October 2012

420 Million hosts that responded to ICMP Ping at least 2 times between June and October 2012
Source: Carna Botnet

http://census2012.sourceforge.net

Autonomous Systems



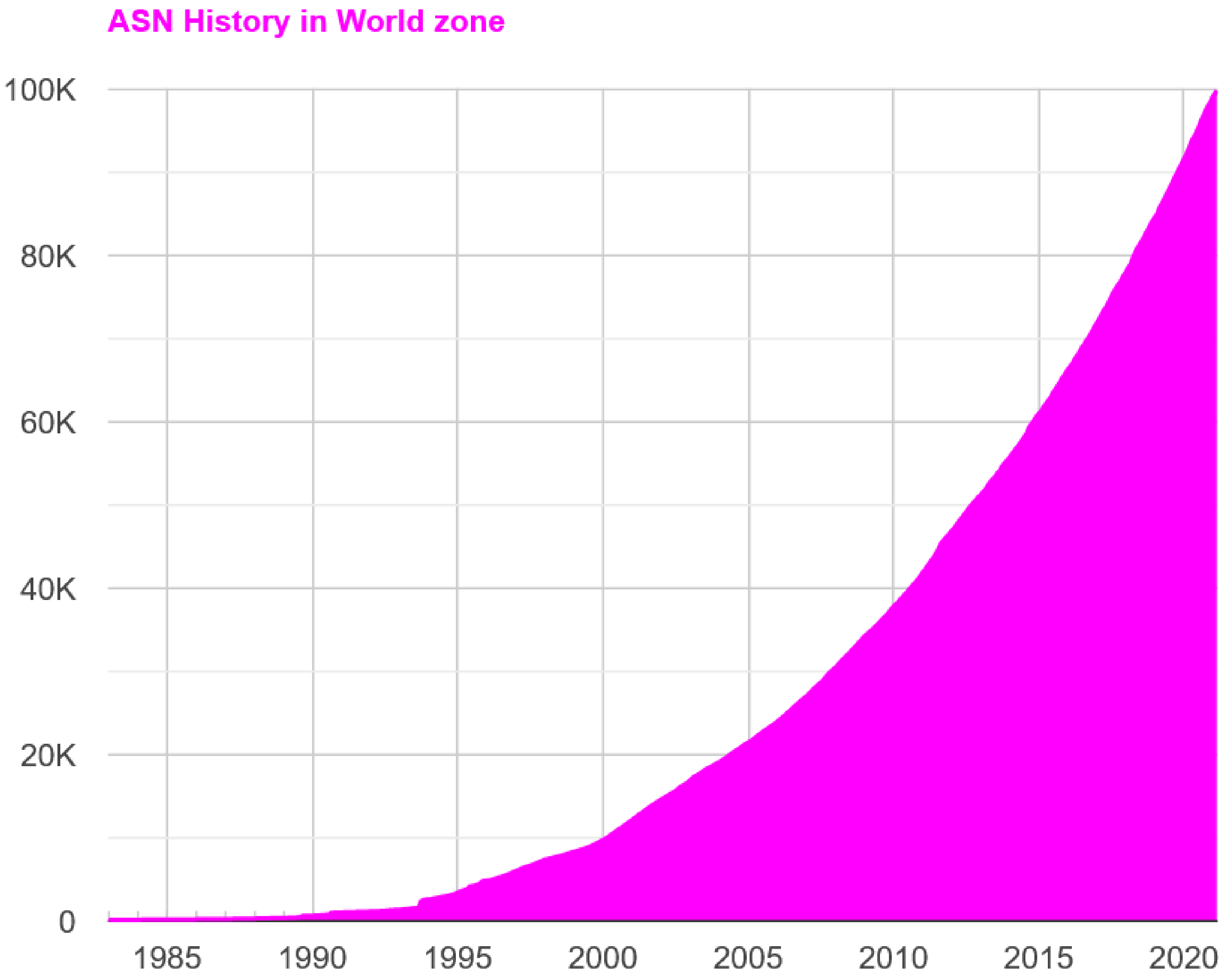
AS: collection of connected IP routing prefixes belonging to a single administrative entity

Presents a common routing policy to the internet

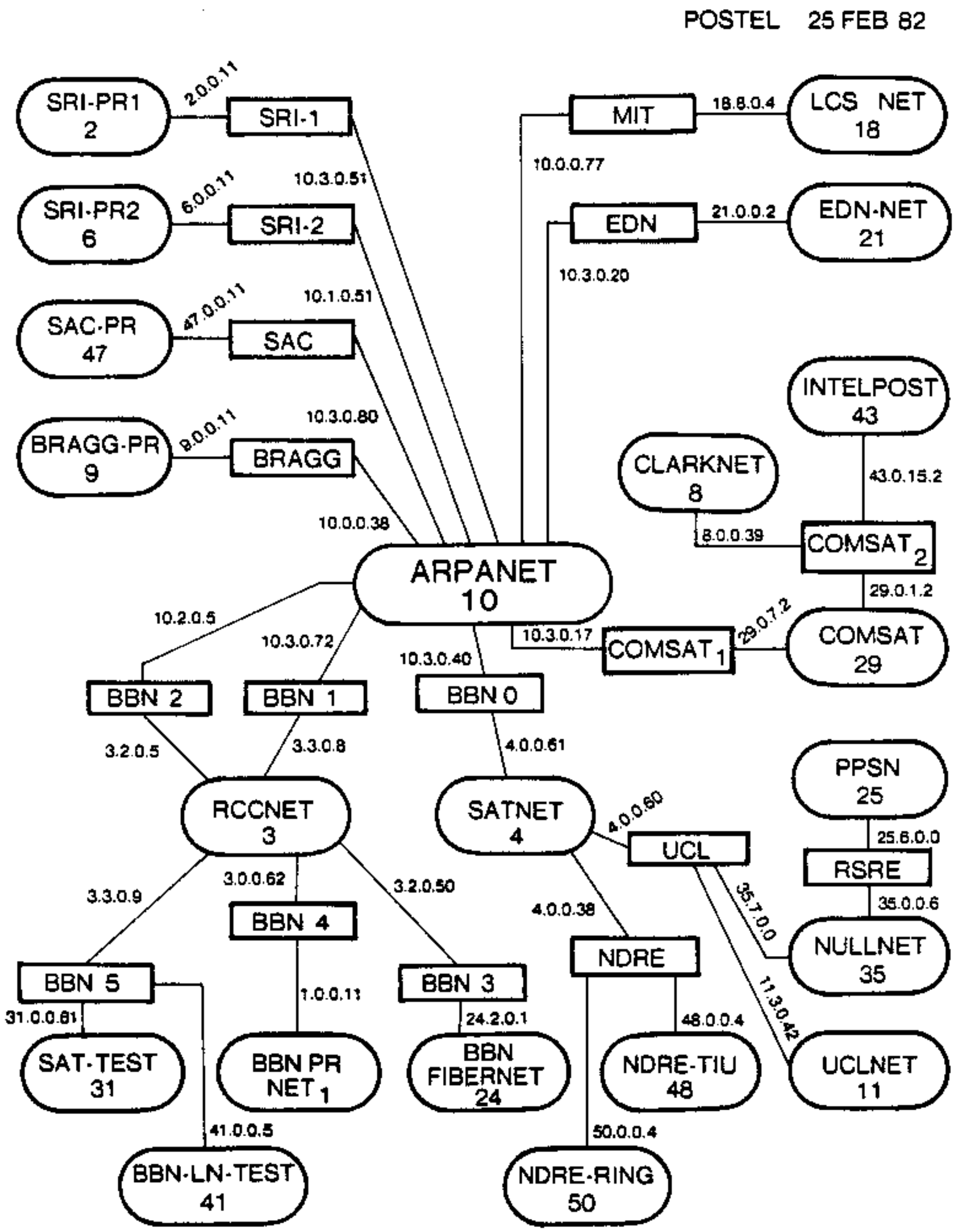
AS number defined as 16-bit integer

99,857 ASNs as of February 2021, assigned by IANA

```
mikepo@konami:~> nslookup hexlab.cs.stonybrook.edu

Name:    hexlab.cs.stonybrook.edu
Address: 130.245.42.42

mikepo@konami:~> whois 130.245.42.42

NetRange:       130.245.0.0 - 130.245.255.255
CIDR:           130.245.0.0/16
NetName:        SUNYSB-CS
NetHandle:      NET-130-245-0-0-1
Parent:         NET130 (NET-130-0-0-0-0)
NetType:        Direct Assignment
OriginAS:
Organization:   State University of New York at Stony Brook (SUNYASB)
RegDate:        1988-10-25
Updated:        2015-04-14
Ref:            https://rdap.arin.net/registry/ip/130.245.0.0

mikepo@konami:~> whois -h whois.cymru.com 130.245.42.42

AS      | IP               | AS Name
5719    | 130.245.42.42    | SUNYSB, US
```



https://www-public.imtbs-tsp.eu/~maigron/RIR_Stats/RIR_Delegations/World/ASN-ByNb.html



Map of the internet, 1982

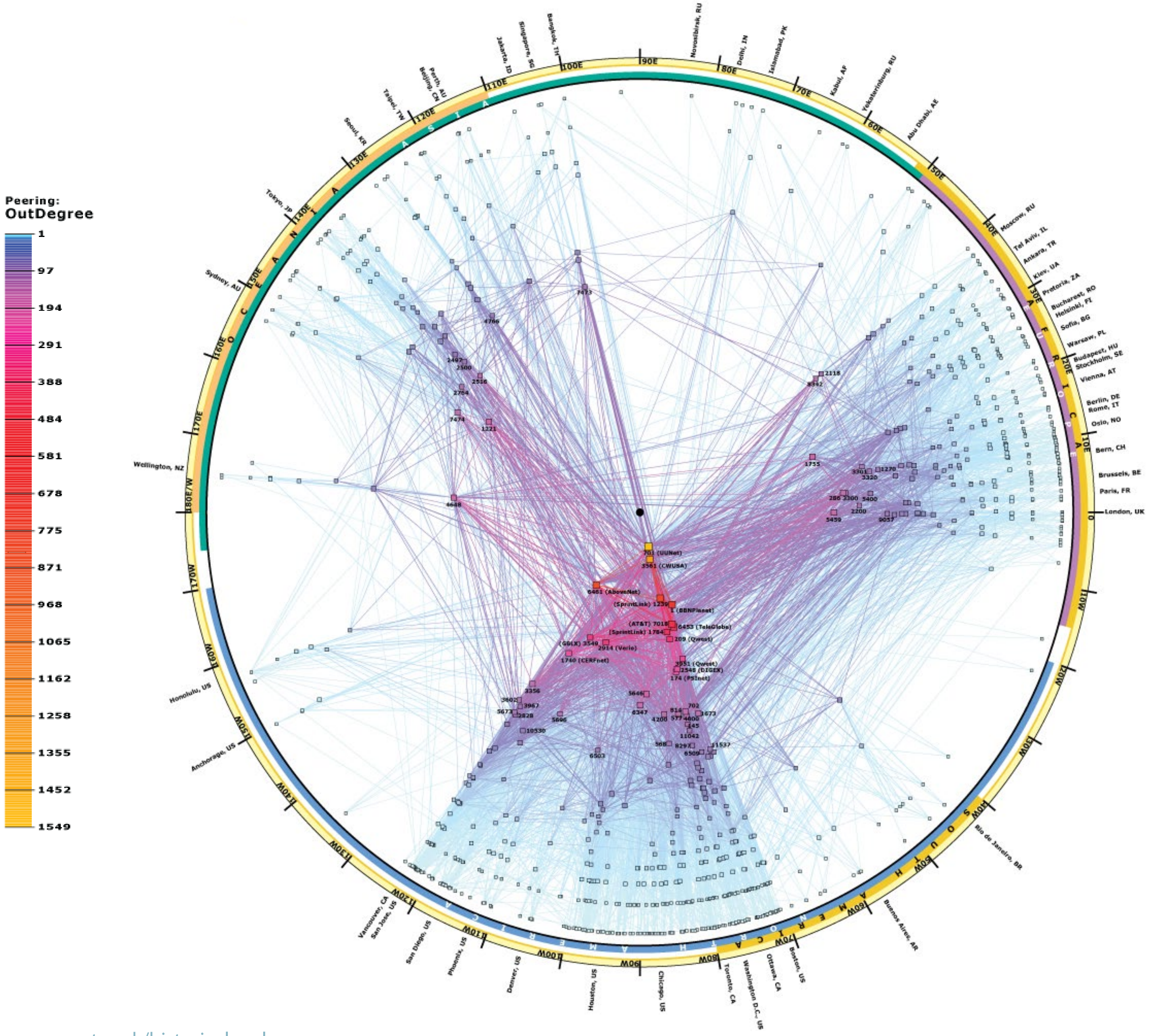
Ovals: sites/networks
Rectangles: routers

CAIDA's IPv4 AS Core AS-level Internet Graph

Skitter
January 2000

220,533 IP addresses

5,107 ASes

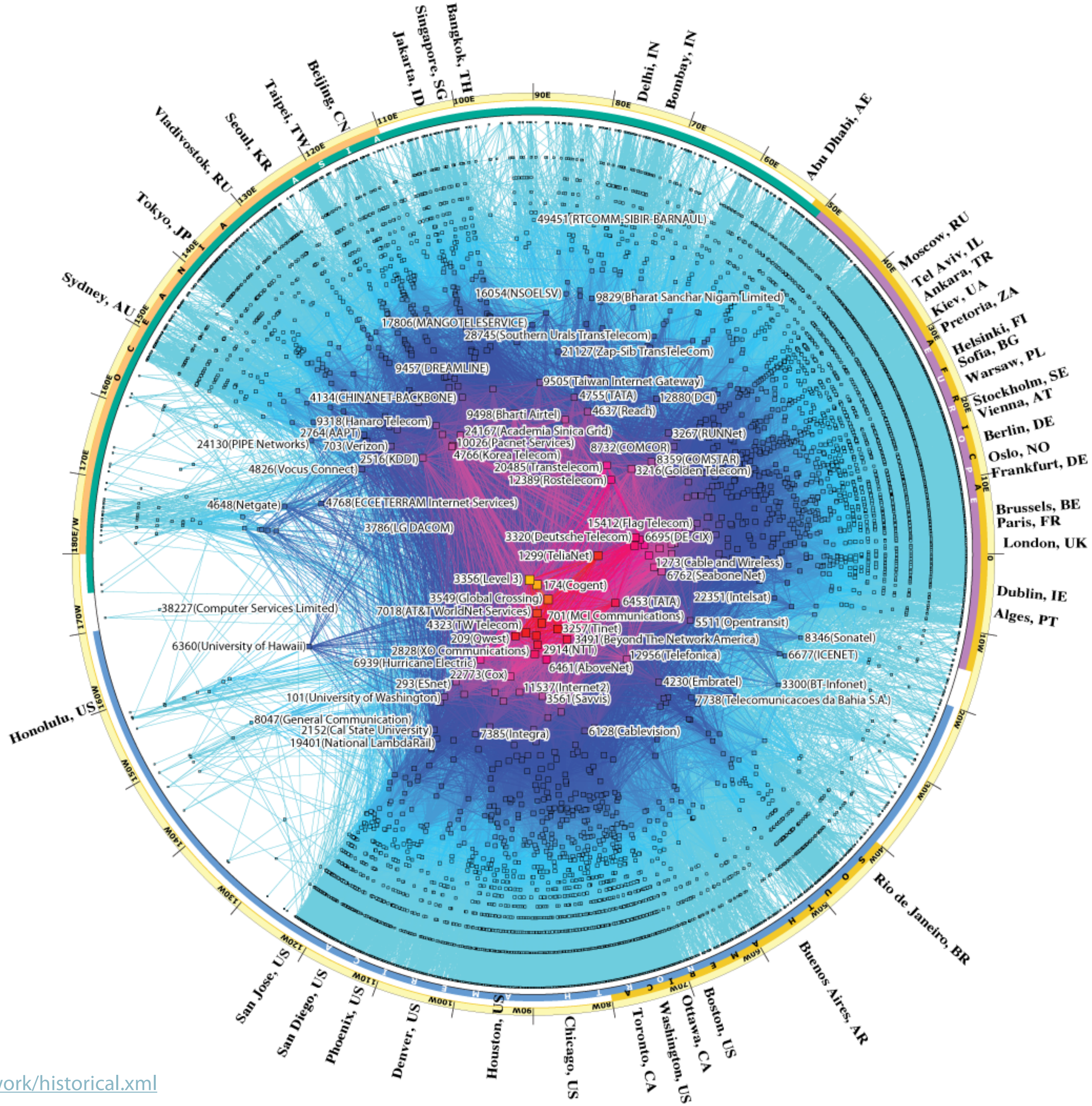


CAIDA's IPv4 AS Core
AS-level Internet Graph

Archipelago
August 2010

16,802,061 IP addresses

26,702 ASes

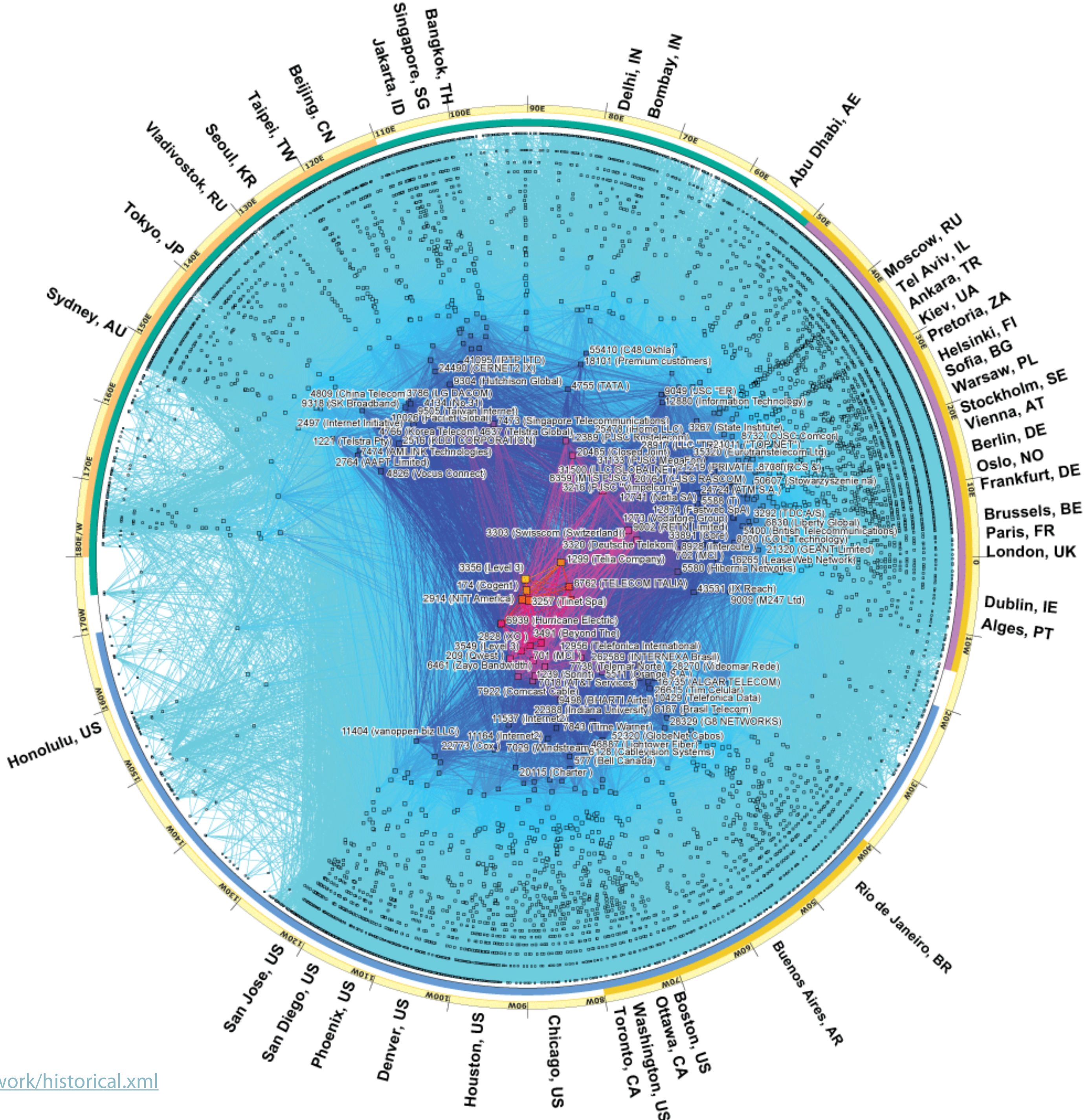


CAIDA's IPv4 AS Core AS-level Internet Graph

Archipelago
February 2017

50 million IP addresses

47,610 ASes



Internet Routing

Routers speak to each other to establish internet paths

- Exchange topology and cost information
- Calculate the best path to each destination

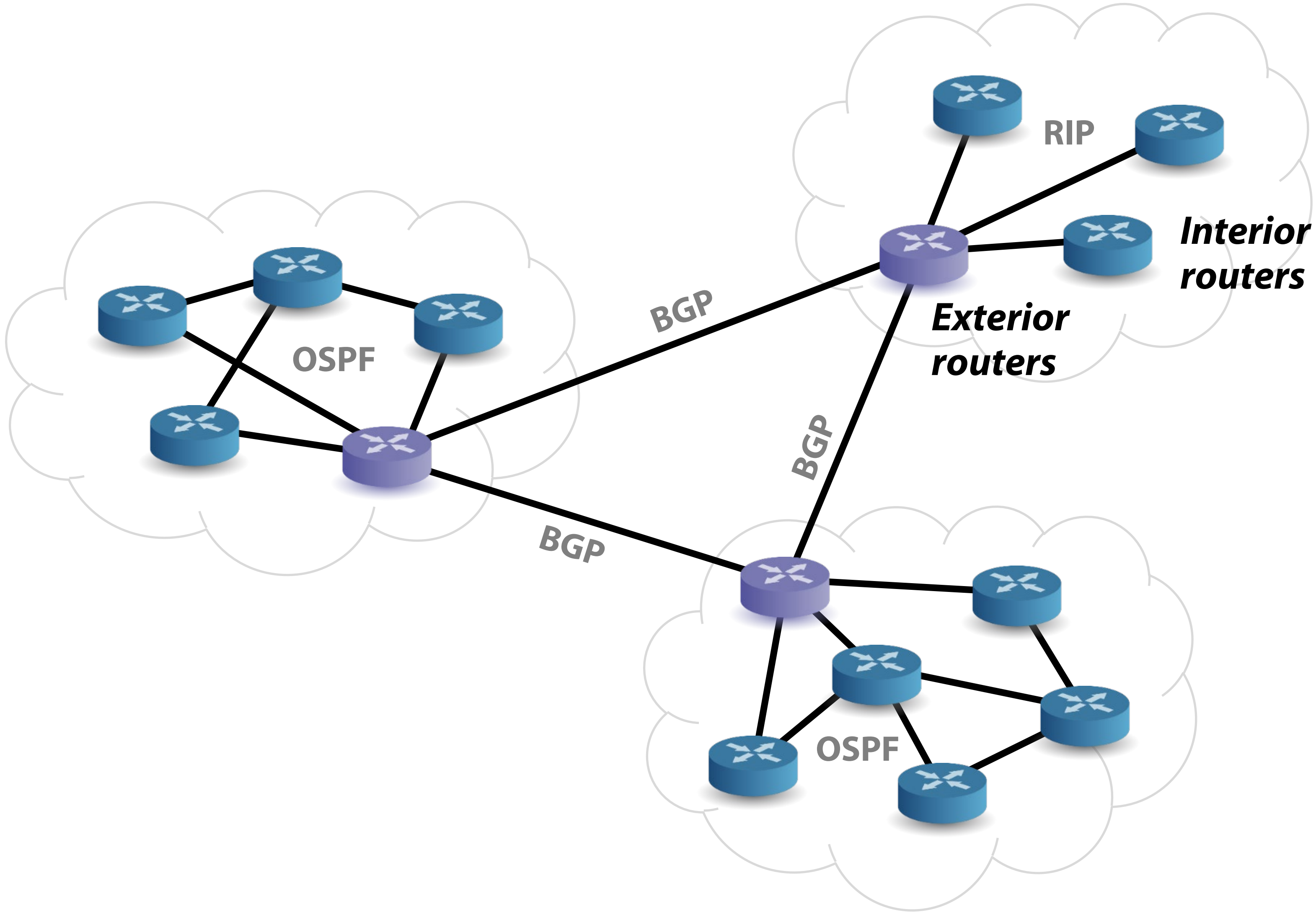
Intra-domain routing: set up routes within a single network/AS

- **RIP** (Routing Information Protocol): distance vector
- **OSPF** (Open Shortest Path First): link state

Inter-domain routing: set up routes between networks

- **BGP** (Border Gateway Protocol)
- Advertisements contain a prefix and a list of ASes to traverse to reach that prefix

Internet Routing



BGP (Border Gateway Protocol)

The de facto standard inter-AS routing protocol in today's Internet

- BGP is what enables subnets to advertise their existence to the rest of the Internet

Main goals:

- Obtain subnet reachability information from neighboring ASs
- Propagate the reachability information to all internal routers
- Determine "good" routes to subnets based on the obtained reachability information and the policies of the involved ASes

Path-vector routing protocol

- Maintains path information that is updated dynamically
- Makes routing decisions based on paths, network policies, or rules configured by network administrators

Root Causes of BGP Security Issues

No authentication of path announcements

- Neighbor adjacencies can be "secured" using MD5 digests

BGP messages are sent over TCP connections

- All the usual problems: eavesdropping, content manipulation, …

Misconfigurations are easy

- BGP is a complex protocol, with complex interactions

Attackers can lie to other routers

Routing Attacks

Blackholing

False route advertisements to attract and drop traffic

Redirection

Force some or all traffic to take a different network path ➔ sniffing, interception (MitM), flooding/congestion

Instability

Frequent advertisements and withdrawals, or increased BGP traffic to cause connectivity disruption

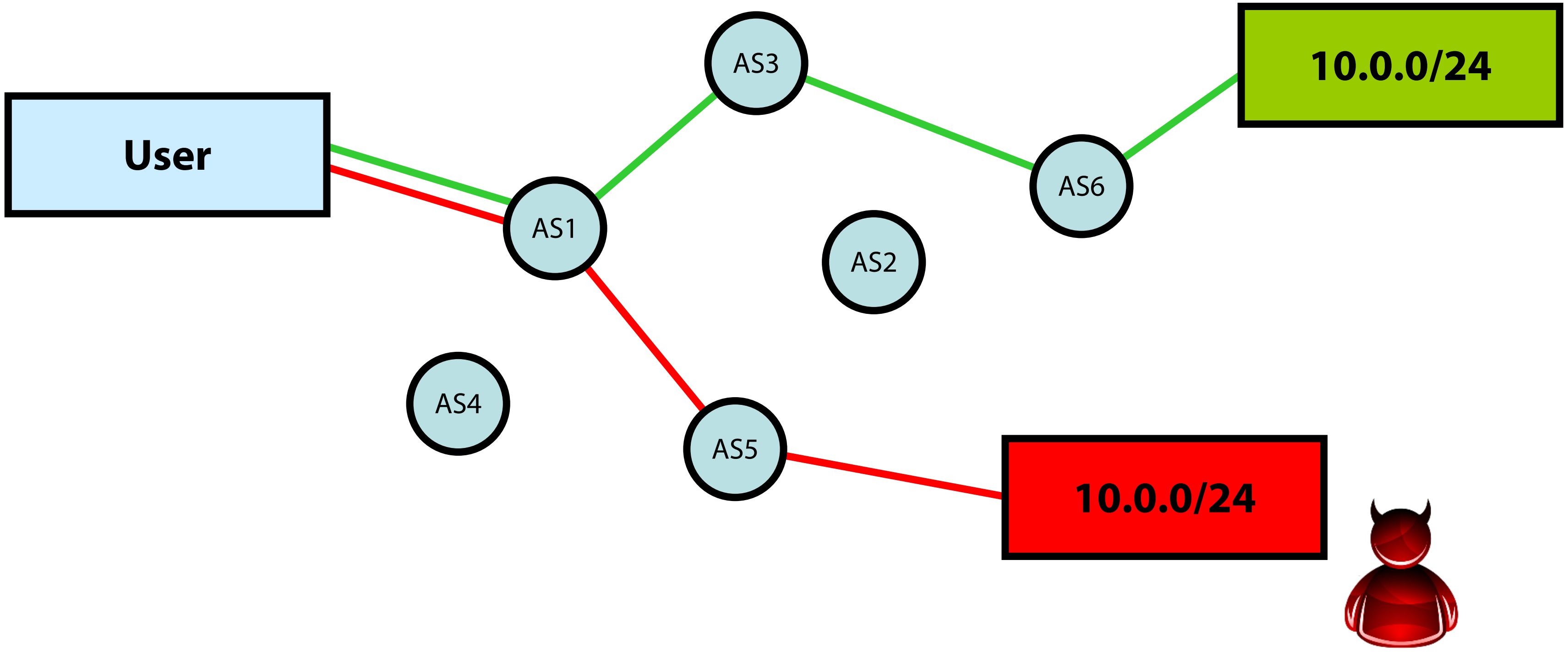
How?

Misconfigurations, insider attacks, compromised routers, BGP traffic manipulation, …

Prefix Hijacking

Announce someone else's prefix

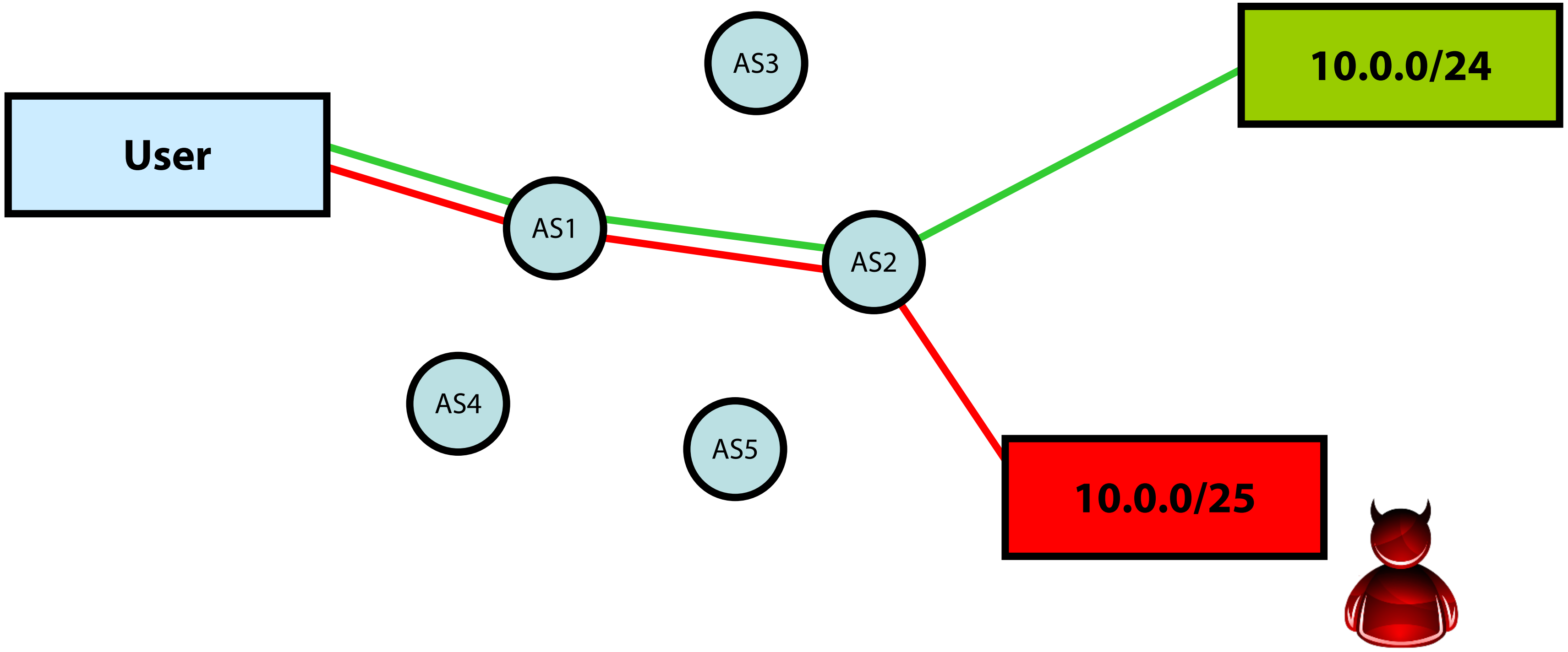
- Victim prefers the *shortest* path



Prefix Hijacking

Announce a more specific prefix than someone else

Victim prefers the *more specific* path



BGP leak causing Interne ×

https://bgpmon.net/bgp-leak-causing-internet-outages-in-japan-and-beyond/

BGPMON Now part of OpenDNS

HOME BLOG ABOUT US PRODUCTS AND SERVICES CLIENT PORTAL

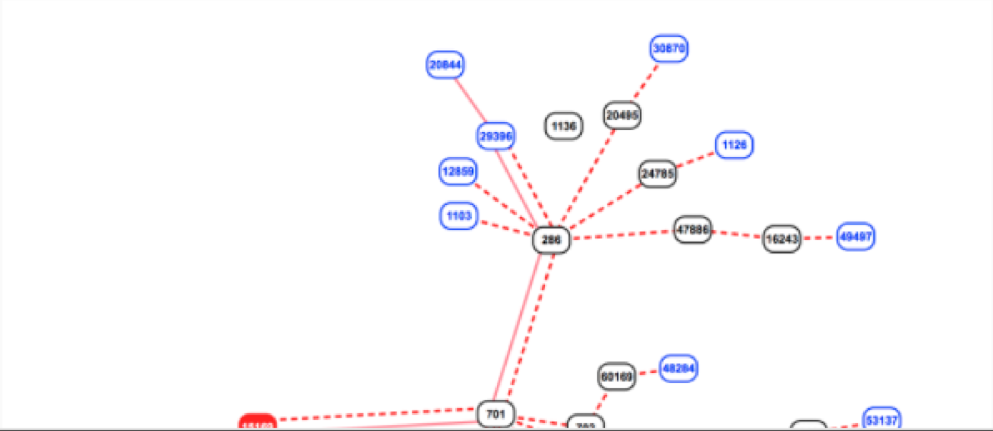
BGP leak causing Internet outages in Japan and beyond.

Posted by Andree Toonk – August 26, 2017 – BGP instability – No Comments

Yesterday some Internet users would have seen issues with their Internet connectivity, experiencing slowness or parts of the Internet as unreachable. This incident hit users in Japan particularly hard and it caused the Internal Affairs and Communications Ministry of Japan to start an investigation into what caused the large-scale internet disruption that slowed or blocked access to websites and online services for dozens of Japanese companies.

In this blog post we will take a look at the root cause of these outages, who was affected and what networks were involved.

Starting at 03:22 UTC yesterday (aug 25) followers of @BGPstream would have seen an increase in alerts involving Google. The BGPstream alerts were informing us that Google was announcing the peering lan prefixes of a few well known Internet exchanges. This in itself is actually a fairly common type of incident and typically indicates something isn't quite right within the networks hijacking those prefixes and so these alerts were the first clues that something wasn't quite right with Google's BGP advertisements.



Latest Tweets

Tweets by @bgpmon

BGPmon.net
@bgpmon

New blog: Route leak via Google and Verizon causing internet outages in japan and beyond
bgpmon.net/bgp-leak-causi...

Aug 26, 2017

BGPmon.net Retweeted

bgpstream
@bgpstream

BGP,OT,KP,Korea, Democratic People's Republic of,-,Outage affected 4 prefixes,
bgpstream.com/event/95347

Aug 14, 2017

BGPmon.net
@bgpmon

Another Internet outage in Syria. Interestingly one remaining Syrian telecom network still BGP visible 91.144.0.0/20
twitter.com/bgpstream/stat...

Embed View on Twitter

Pakistan's Accidental You ×

www.wired.com/2008/02/pakistans-accid/

WIRED GEAR SCIENCE ENTERTAINMENT BUSINESS SECURITY DESIGN OPINION MAGAZINE VIDEO INSIDER SUBSCRIBE

THREAT LEVEL | Glitches and Bugs | Sunshine and Secrecy

FOLLOW WIRED

Pakistan's Accidental YouTube Re-Routing Exposes Trust Flaw in Net

BY RYAN SINGEL 02.25.08 | 10:37 AM | PERMALINK

Share 4 Tweet 4 g+1 0 in Share Pin it

Government: you have to block this YouTube video

Pakistan Telecom: sure

Use URL filtering?

Nope

Change the DNS record?

Nope

Use IP blocking?

Nope

Blackhole 208.65.153.0/24?

Yeah!

PTA

Corrigendum- Most Urgent

GOVERNMENT OF PAKISTAN
PAKISTAN TELECOMMUNICATION AUTHORITY
ZONAL OFFICE PESHAWAR
Plot-11, Sector A-3, Phase-V, Hayatabad, Peshawar.
Ph: 091-9217279- 5829177 Fax: 091-9217254
www.pta.gov.pk

NWFP-33-16 (BW)/06/PTA   February ,2008

Subject: **Blocking of Offensive Website**

Reference: This office letter of even number dated 22.02.2008.

I am directed to request all ISPs to immediately block access to the following website

URL: http://www.youtube.com/watch?v=o3s8jtvvg00

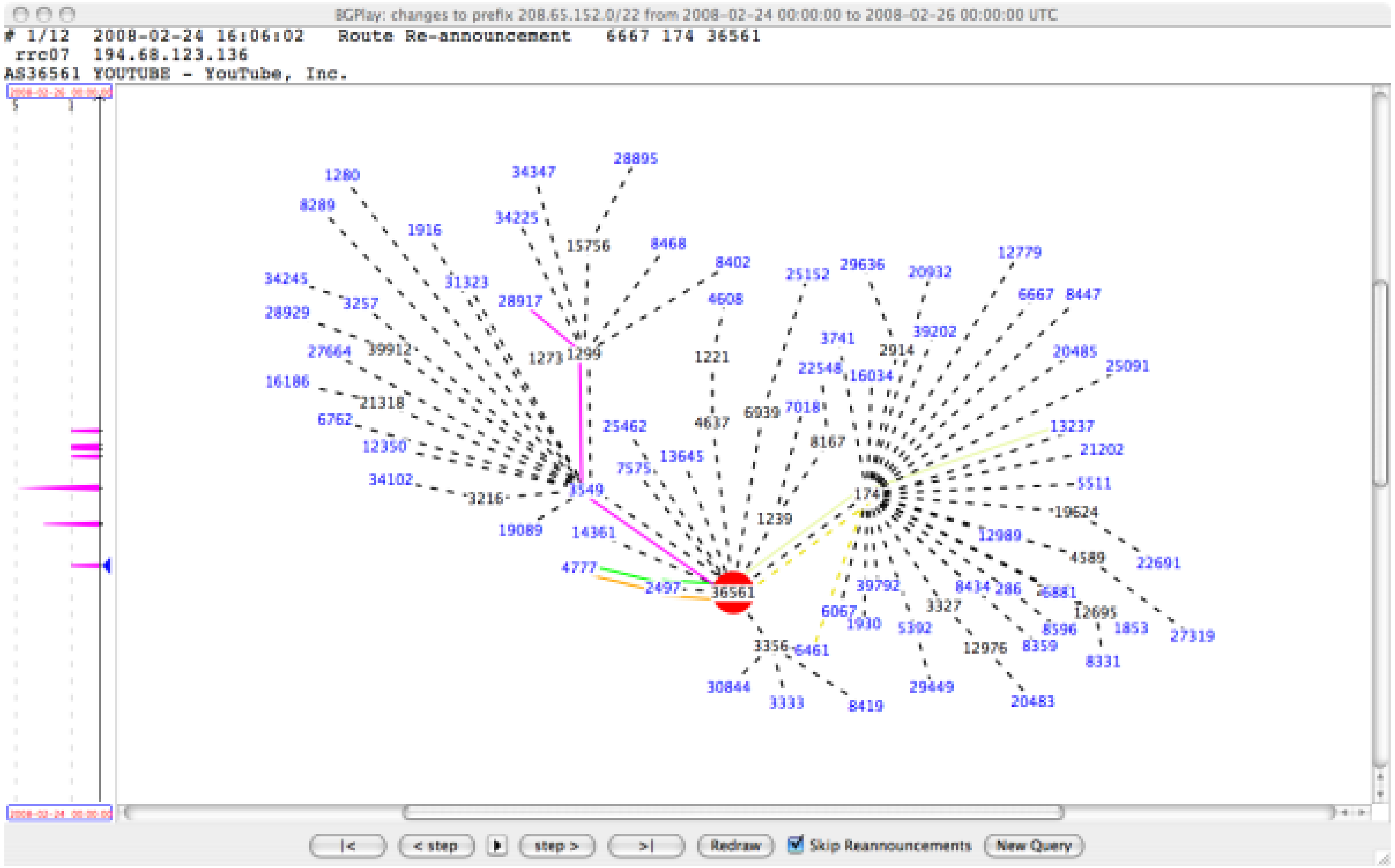
IPs: 208.65.153.238, 208.65.153.253, 208.65.153.251

Compliance report should reach this office through return fax or at email peshawar@pta.gov.pk today please.

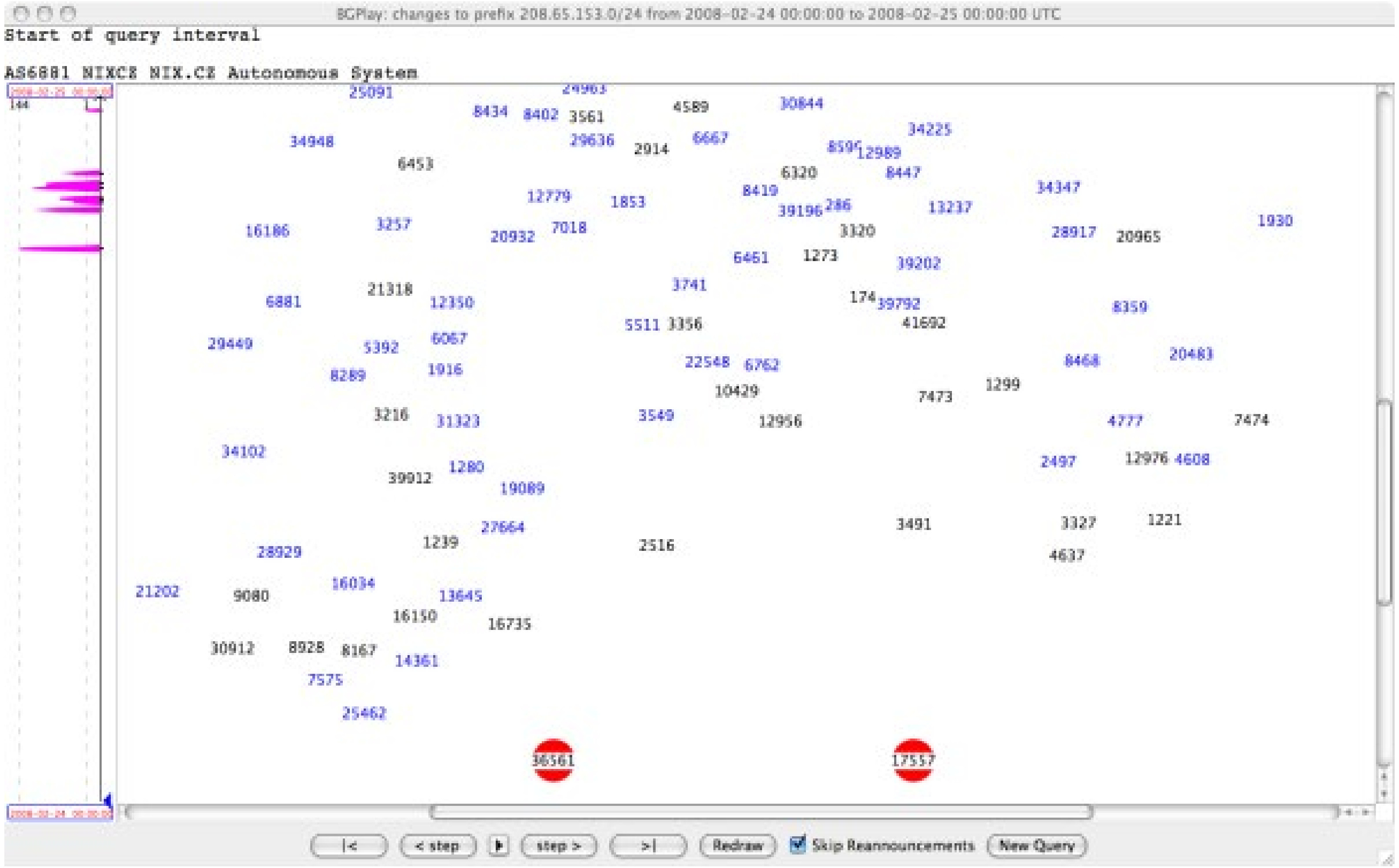
Deputy Director
(Enforcement)

To:
1. M/s Comsats, Peshawar.
2. M/s GOL Internet Services, Peshawar.
3. M/s Cyber Internet, Peshawar.
4. M/s Cybersoft Technologies, Islamabad.
5. M/s Paknet, Limited, Islamabad
6. M/s Dancom, Peshawar.
7. M/s Supernet, Peshawar.

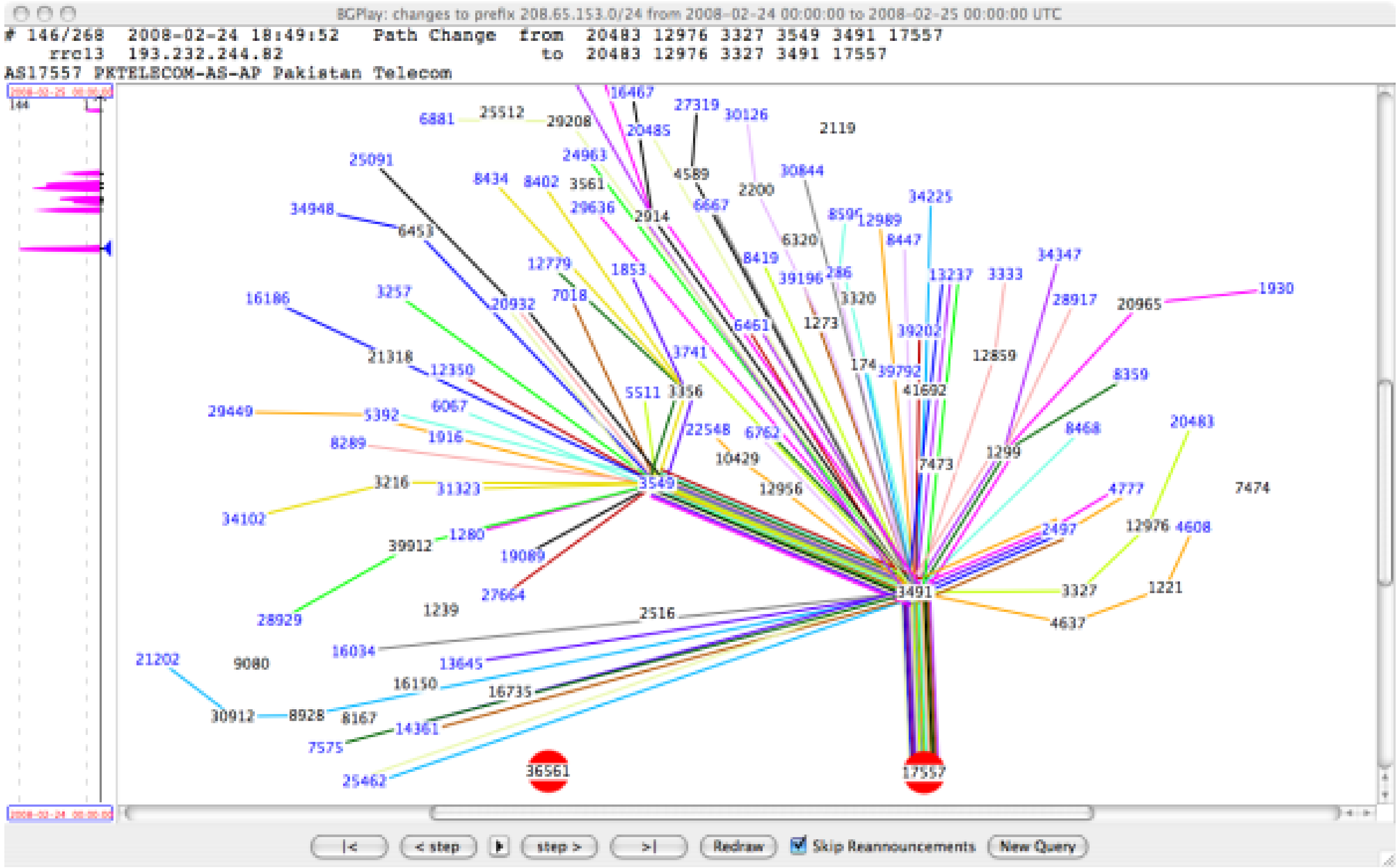
AS36561 (YouTube) announces 208.65.152.0/22



The prefix 208.65.153.0/24 is not announced on the Internet before the event



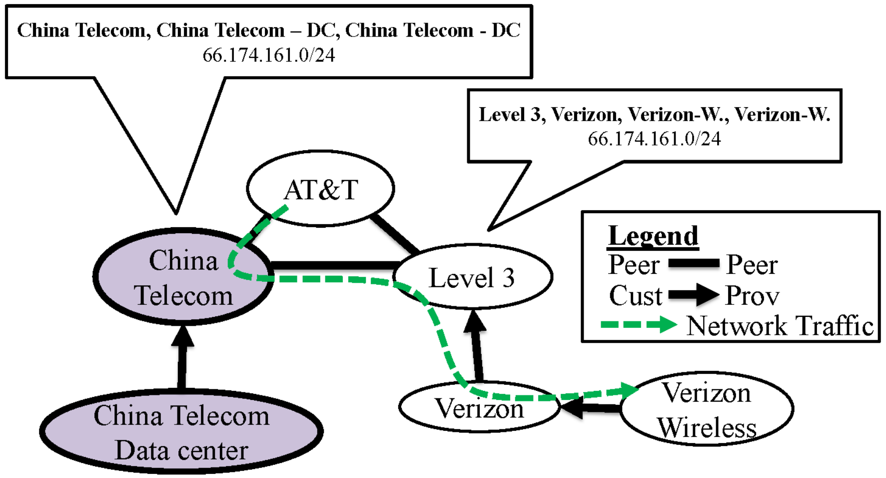
AS17557 (Pakistan Telecom) announces 208.65.153.0/24



Other Notable Incidents

April 2010: China Telecom announced bogus paths to 50,000 IP prefixes

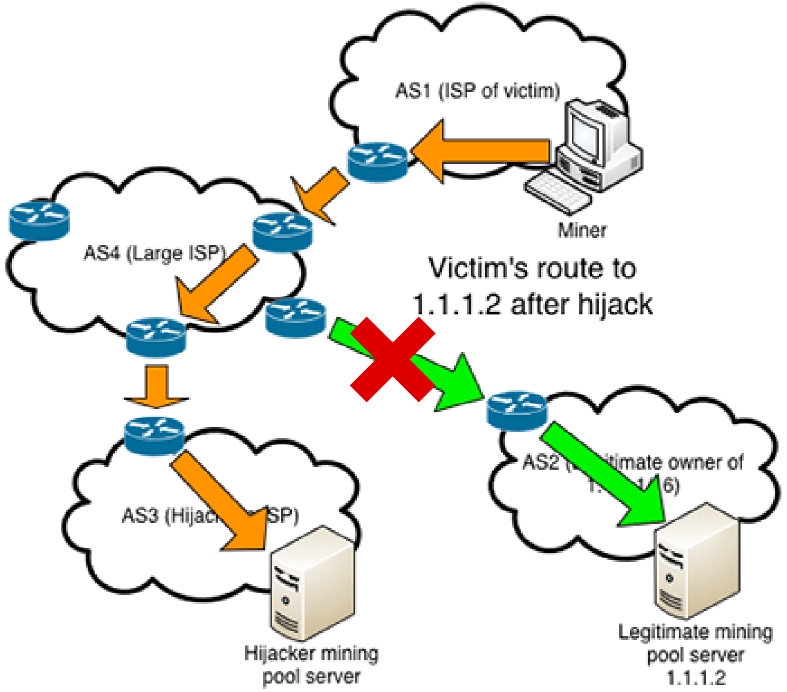
Enabled traffic interception



February 2014: hijacking of 51 networks (incl. Amazon, Digital Ocean, OVH)

Miner connections were redirected to an attacker-controlled mining pool

Attacker collected the miners' profit (estimated $83,000 in 4 months)



Popular Destinations rerouted to Russia

Posted by Andree Toonk - December 12, 2017 - Hijack - No Comments

Early this morning (UTC) our systems detected a suspicious event where many prefixes for high profile destinations were being announced by an unused Russian Autonomous System.

Starting at 04:43 (UTC) 80 prefixes normally announced by organizations such Google, Apple, Facebook, Microsoft, Twitch, NTT Communications and Riot Games were now detected in the global BGP routing tables with an Origin AS of 39523 (DV-LINK-AS), out of Russia.

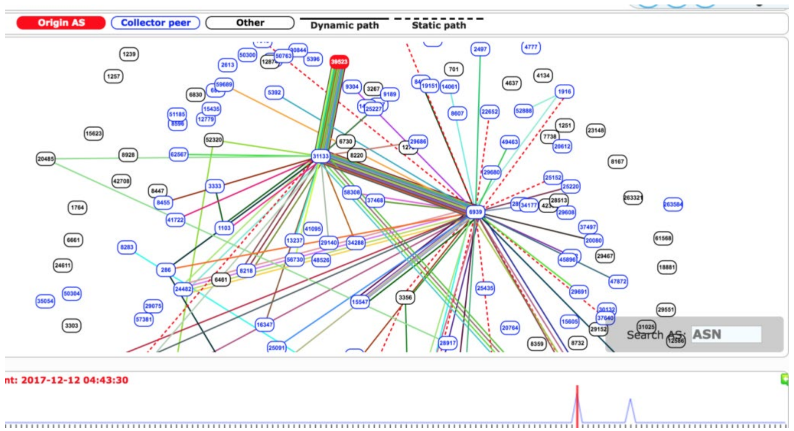
Looking at timeline we can see two event windows of about three minutes each. The first one started at 04:43 UTC and ended at around 04:46 UTC. The second event started 07:07 UTC and finished at 07:10 UTC.

Even though these events were relatively short lived, they were significant because it was picked up by a large number of peers and because of several new more specific prefixes that are not normally seen on the Internet. So let's dig a little deeper.

One of the interesting things about this incident is the prefixes that were affected are all network prefixes for well known and high traffic internet organizations. The other odd thing is that the Origin AS 39523 (DV-LINK-AS) hasn't been seen announcing any prefixes for many years (with one exception below), so why does it all of sudden appear and announce prefixes for networks such as Google?

Latest Tweets

Tweets by @bgpmon



China Telecom has been using poisoned internet routes to suck up massive amounts of US and Canadian internet traffic

CORY DOCTOROW / 6:15 AM FRI OCT 26, 2018

In a new paper published in the journal *Military Cyber Affairs* researchers from the US Naval War College and Tel Aviv University document the use of BGP spoofing by China Telecom to redirect massive swathes of internet traffic through the company's routers as part of state military and commercial espionage efforts.

BGP is a notoriously insecure protocol used to route internet traffic; by design it is dynamic and responsive, moving traffic away from congested routes and onto those with more capacity: this flexibility can be exploited to force traffic to route through surveillance chokepoints, as well as for censorship (publishing BGP routes to censored services that dead-end in nonexistent addresses are a common technique in repressive regimes).

The researchers logged global BGP route announcements and discovered China Telecom publishing bogus routes that sucked up massive amounts of Canadian and US traffic and pushed it through Chinese listening posts. Much of today's internet traffic is still unencrypted, meaning that the entities monitoring these listening posts would have been able to read massive amounts of emails, instant messages and web-sessions.

Mitigating BGP Threats

Neighbor authentication

- Only authorized peers can establish a given BGP neighbor relationship

TTL check

- Most external peering sessions are established between adjacent routers
- Good idea: set TTL=1 ➔ an attacker X hops away can still set TTL=1+X
- Better idea: set TTL=255 and accept only packets with TTL=255 ➔ an attacker further away cannot spoof such a packet

BGP prefix restrictions, sanity checks, and filtering

- Accept only a certain number of prefixes, ignore unwanted/illegal prefixes, limit the number of accepted AS path segments, …

ACLs to explicitly permit only authorized BGP traffic

- According to existing security policies and configurations

Securing BGP

Secure BGP (S-BGP)

- Each node signs its announcements

Resource Public Key Infrastructure (RPKI)

- Certified mapping from ASes to public keys and IP prefixes

Secure origin BGP (soBGP)

- Origin authentication + trusted database that guarantees that a path exists

BGPPSec

- Allow recipients to validate the AS path included in update messages

Many deployment challenges

- No complete, accurate registry of prefix ownership
- Need for a public-key infrastructure
- Cannot react rapidly to changes in connectivity
- Cost of cryptographic operations
- Incremental deployment not always possible