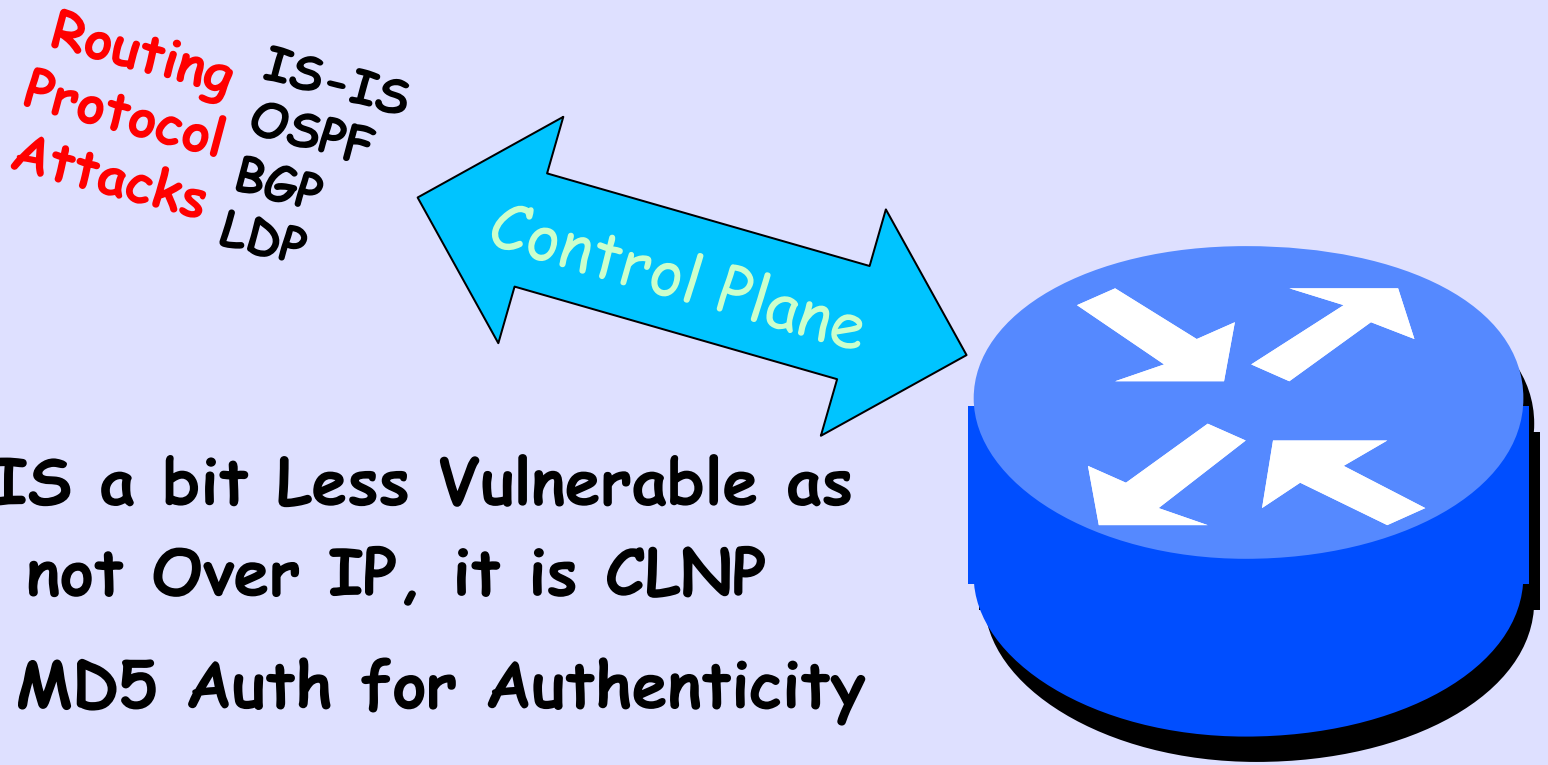
Day 3-1-1
Protecting Routing Protocols

Agenda

- Some Technical Background
- Mis-Origination - YouTube Incident
- The RPKI – Needed Infrastructure
- RPKI-Based Origin Validation
- Use the GUI to make ROAs and look at the result on a router
- Build your own Relying Party Server
- Discussion

Remember This One?

- Routing was Designed With no Concern for Security
- Attacks can be Close or Remote, e.g. YouTube Incident



- IS-IS a bit Less Vulnerable as it is not Over IP, it is CLNP
- Use MD5 Auth for Authenticity
- Other Protections Very Active in IETF

What is Routing Security?

- Defending routers against attacks that are similar to attacks on hosts
- But the unique threat is attackers using routing protocols
  - To divert traffic
  - To alter traffic
- We have some ability to lessen the danger, but not enough!

Protocol Attacks

- The Router is Secured Against Attack
- The Routing Code is Good
- The Attacker is 'Gaming' the Protocol
- Sending Lies Over BGP is the Big Threat
- But IGP, OSPF or IS-IS may also be Attacked

History of Routing Security

- Radia Perlman dissertation: *Network Layer Protocols with Byzantine Robustness*, 1988
- Bellovin: *Security Problems in the TCP/IP Protocol Suite*, 1989
- Work Begins in 1996
- Kent et alia two papers in 2000
- Endless Talk in the IETF
- 2005 Serious Work Outside IETF
- 2010-12 RFCs Published, Code by C & J

Why so Little Progress

- The Problems are Technically Very Difficult
- Simple Routing is Already a Very Complex Operational Issue
- It is Not Traditional Communications Security
- Installed Base & Transition Problem

Normal Ops Security

- Protect Router Itself, Like a Host
- TCP/MD5 Session Protection
- ACLs on Everything
- ssh, not telnet. no http, …
- Route Filtering (based on IRR),
- …

A Quick Commercial

Why I Prefer IS-IS

- Simpler than OSPF
- Used in ISPs, not many End Sites
- Over CLNP, the Link Layer, not IP, so Harder to Attack
- IPv4 and IPv6 in One Protocol
- Older and Less Buggy
- Biggest ISPs Used it so Well Debugged

IS-IS

- Is Over the Link Layer
- So Attacker Must be On The Link
- Of Course, a Compromised Neighbor Router is On The Link
- OSPF, BGP, and LDP may be Attacked from a Long Distance

But it Makes No Difference

- Use Either IS-IS or OSPF
- But Protect Them
- Use MD5 Auth/Password to be Sure you have Connected to Right Peer
- Use MD5 Auth to Protect from on-the-wire Attack
- Maybe even ACL Filter Who May Exchange IGP with Each Router

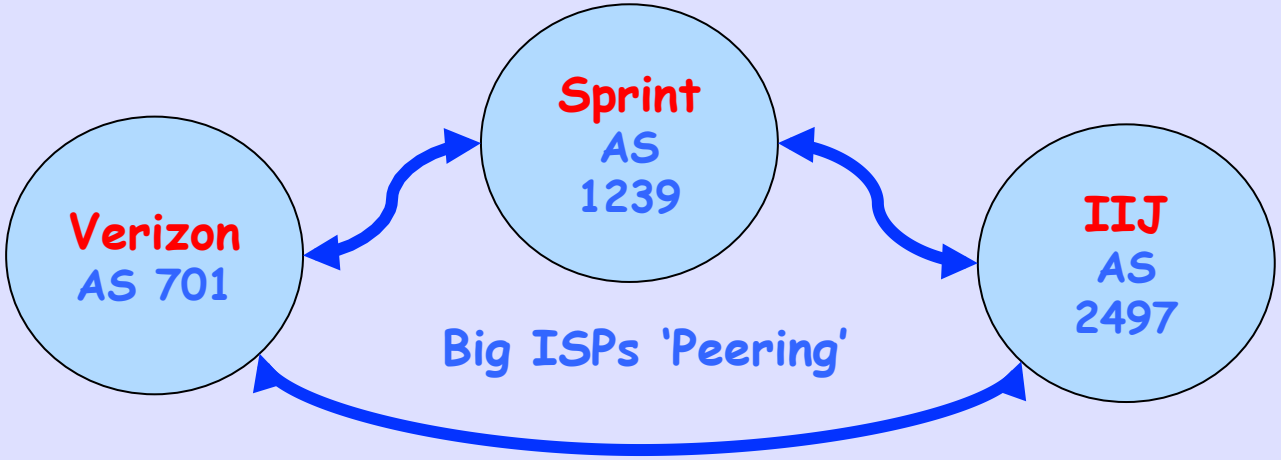
BGP
is the
Big Vulnerability

Basic Protection Same as IGP

- Use MD5 Auth/Password to be Sure you have Connected to Right Peer
- Use MD5 Auth to Protect from on-the-wire Attack
- Maybe even ACL Filter Who May Exchange BGP with Each Router

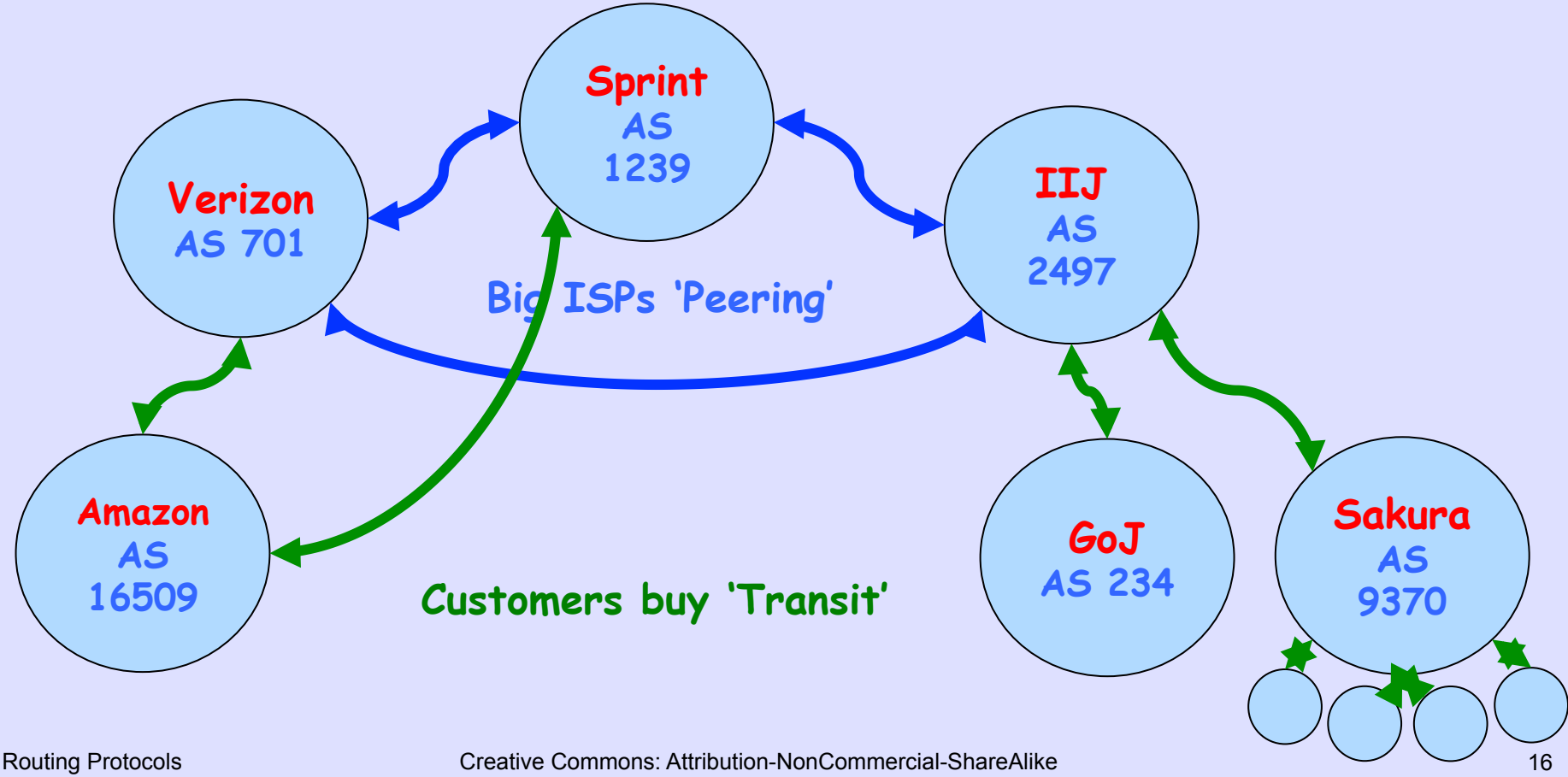
What is an AS?

An ISP or End Site

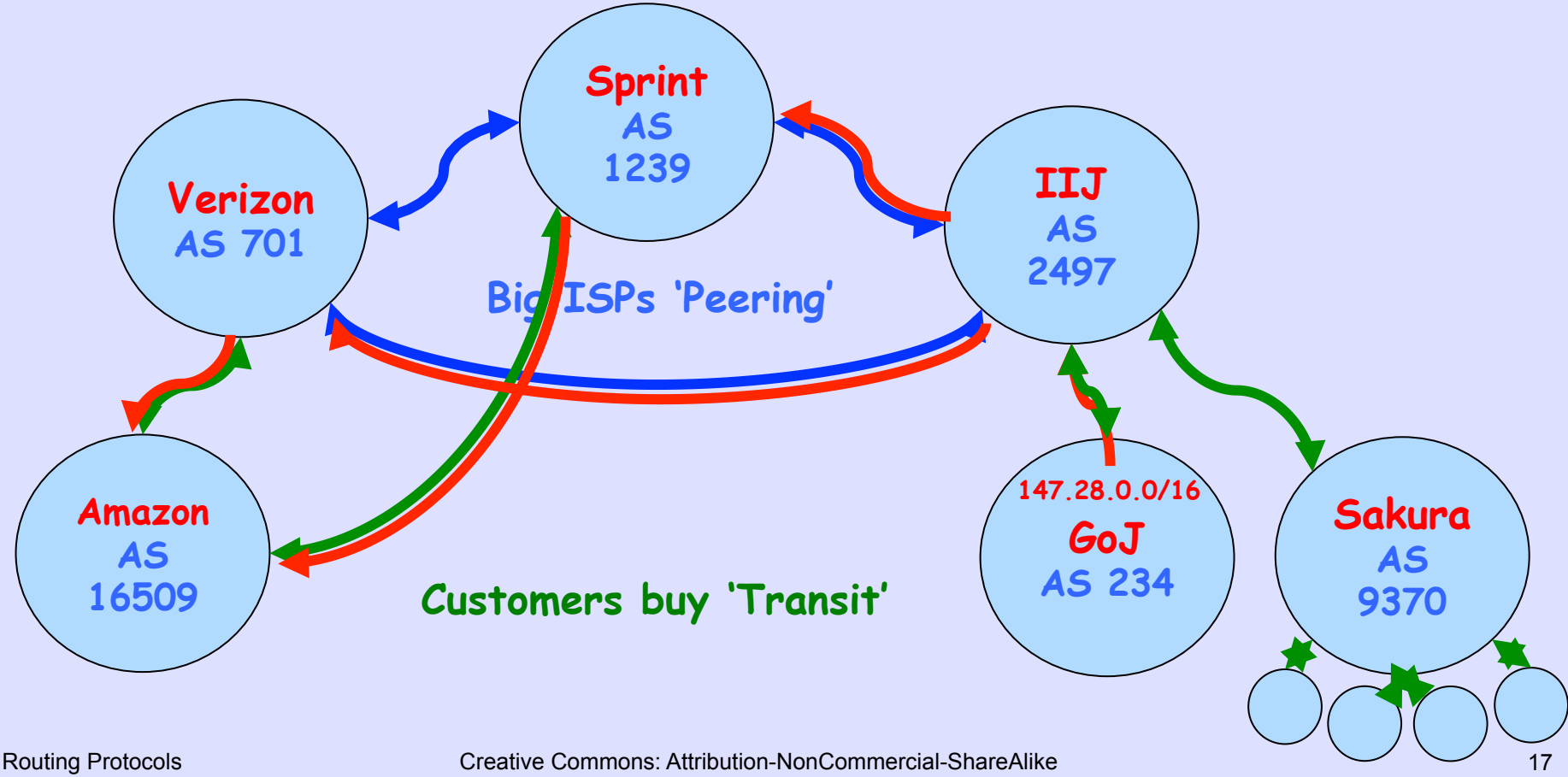


What is an AS?

An ISP or End Site

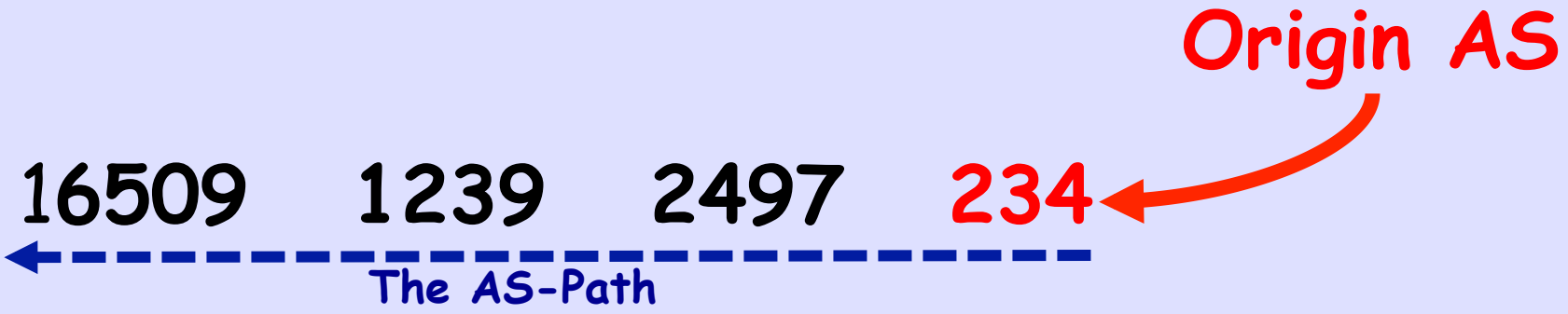


An IP Prefix is Announced & Propagated



From Inside a Router

BGP routing table entry for 147.28.0.0/16

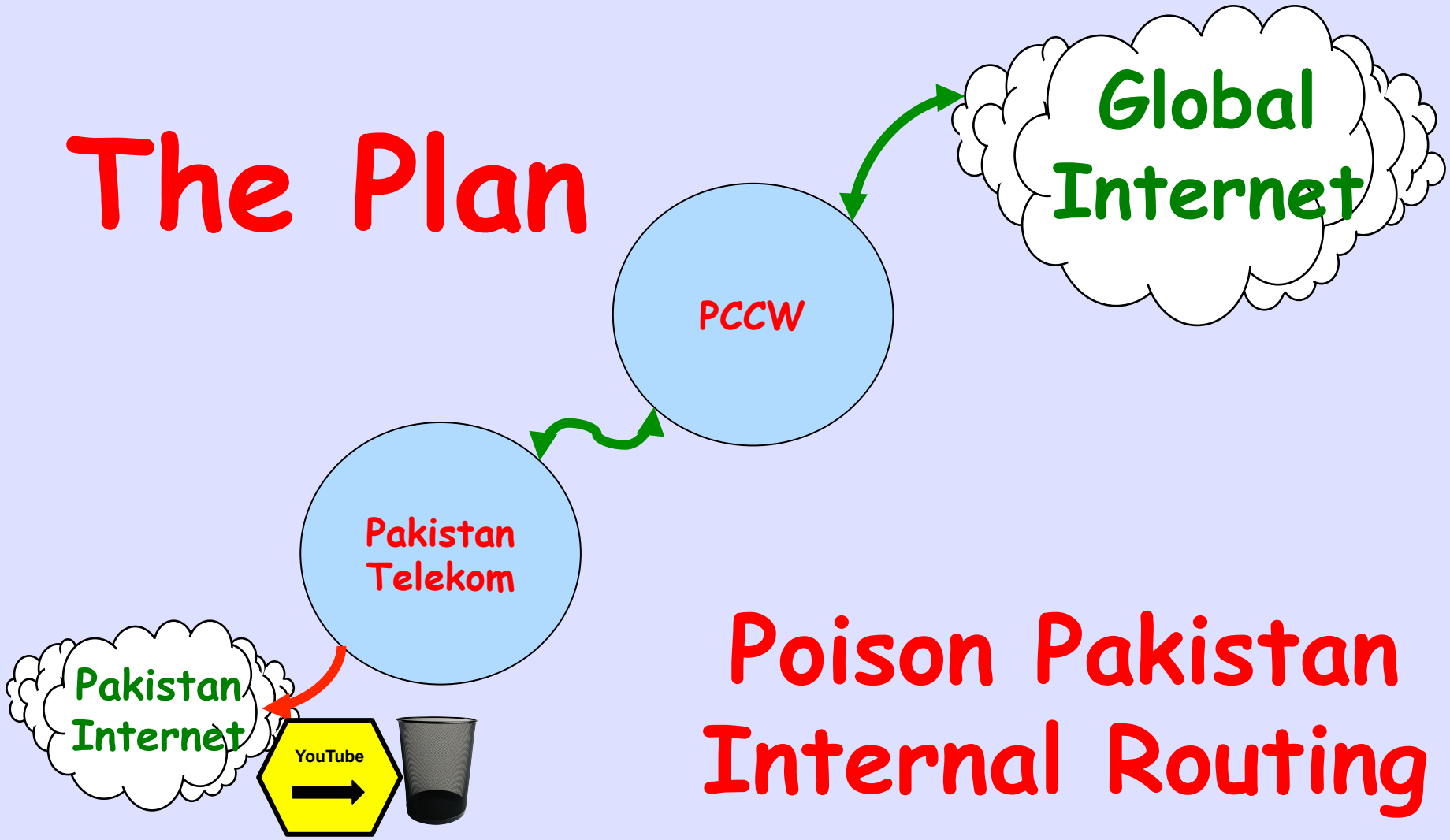


Of Course it's Uglier ☺

```
r1.iad#sh ip bgp 147.28.0.0/16
BGP routing table entry for 147.28.0.0/16, version 21440610
Paths: (2 available, best #1, table default)
  Advertised to update-groups:
     1
  Refresh Epoch 1
  16509   1239   2497   234
    144.232.18.81 from 144.232.18.81 (144.228.241.254)
      Origin IGP, metric 841, localpref 100, valid, external, best
      Community: 3297:100 3927:380
      path 67E8FFCC RPKI State valid
  Refresh Epoch 1
  16509   701  2497   234
    129.250.10.157 (metric 11) from 198.180.150.253 (198.180.150.253)
      Origin IGP, metric 95, localpref 100, valid, internal
      Community: 2914:410 2914:1007 2914:2000 2914:3000 3927:380
      path 699A867C RPKI State valid
```

The YouTube Incident

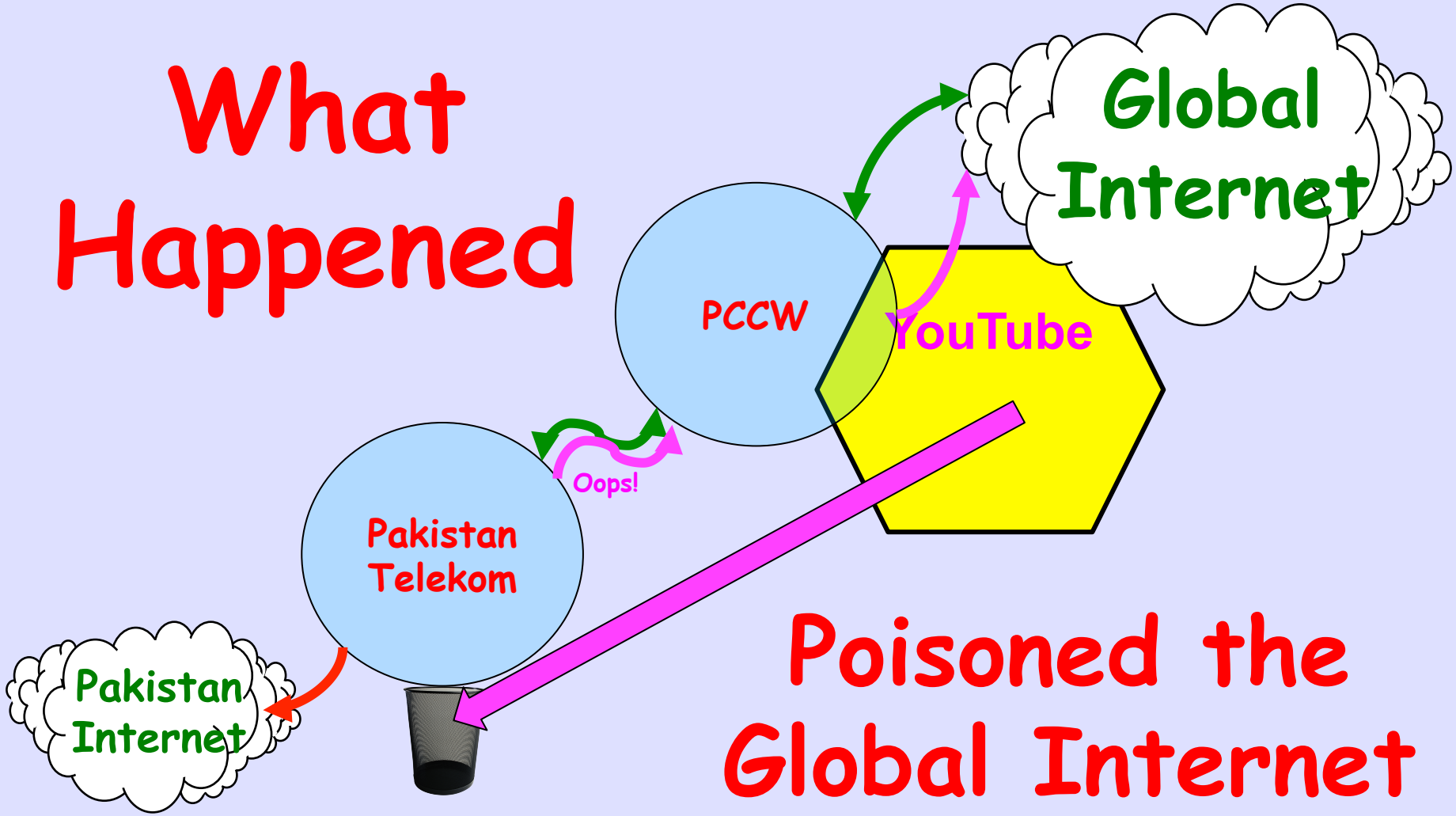
The Plan



Poison Pakistan Internal Routing

The YouTube Incident

What Happened



Poisoned the Global Internet

We Call this *Mis-Origination*

a Prefix is Originated by an AS Which Does Not Own It

I Do Not Call it *Hijacking*

Because that *Assumes* Negative Intent

And These Accidents Happen Every Day

Usually to Small Folk Sometimes to Large

So,

What's the Plan?

Three Pieces

- **RPKI** – Resource Public Key Infrastructure, the Certificate Infrastructure to Support the other Pieces (starting last year)
- **Origin Validation** – Using the RPKI to detect and prevent mis-originations of someone else's prefixes (early 2012)
- **AS-Path Validation** AKA **BGPsec** – Prevent Attacks on BGP (future work)

Why Origin Validation?

- Prevent YouTube accident & Far Worse
- Prevent 7007 accident, UU/Sprint 2 days!
- Prevents most accidental announcements
- Does not prevent malicious path attacks such as the Kapela/Pilosov DefCon attack
- That requires 'Path Validation' and locking the data plane to the control plane, the third step, BGPsec

We Need to be Able to Authoritatively Prove Who Owns an IP Prefix And What AS(s) May Announce It

Prefix Ownership Follows the Allocation Hierarchy

IANA, RIRs, ISPs, …

Resource Public Key Infrastructure (RPKI)

X.509-Based IP Resource PKI

RFCs Have Been Long Published

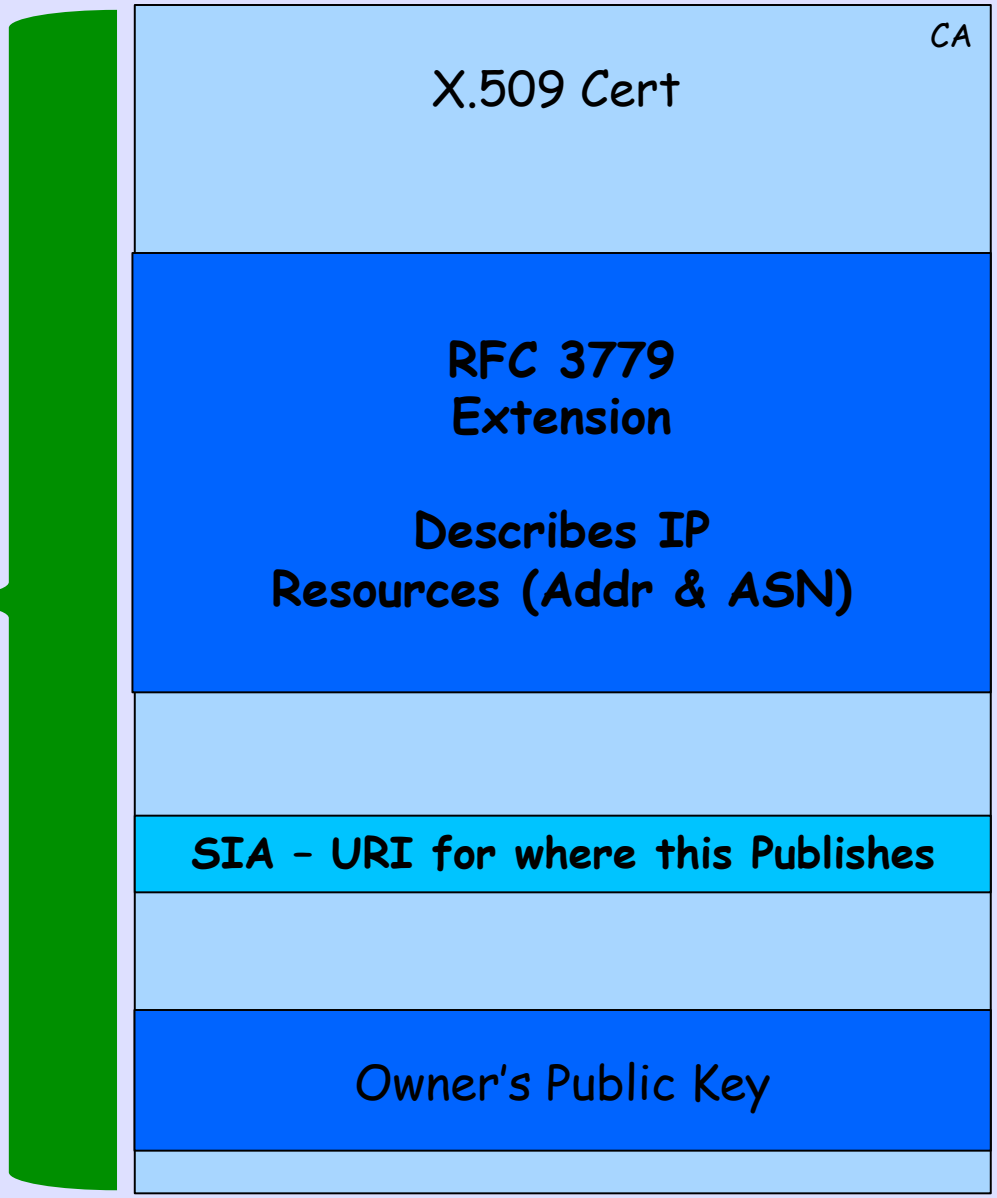
Deployed by All RIRs

ROAs Registered by > 1,000 Operators

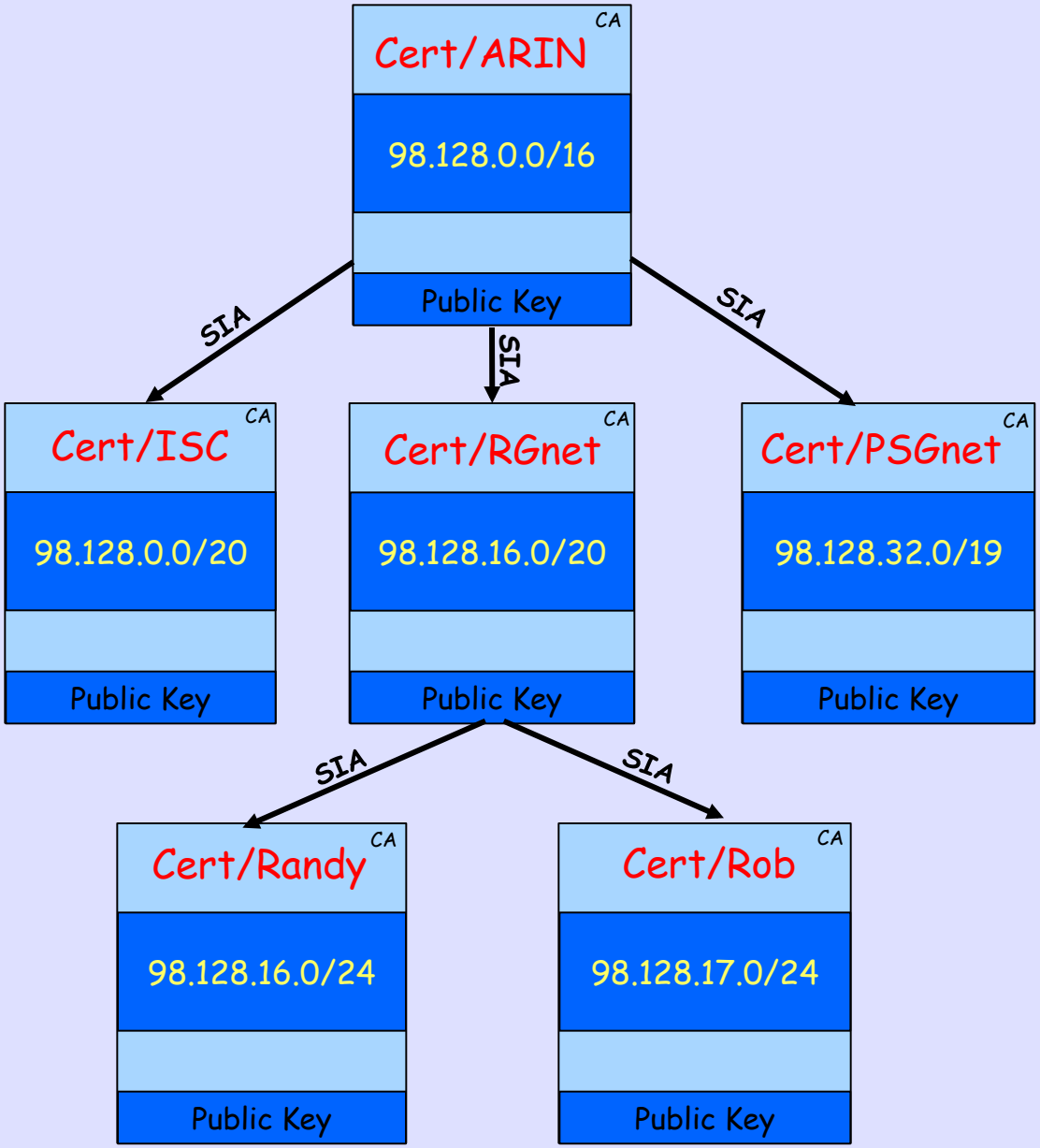
In Live Routers

X.509 Certificate w/ 3779 Ext

Signed by Parent's Private Key

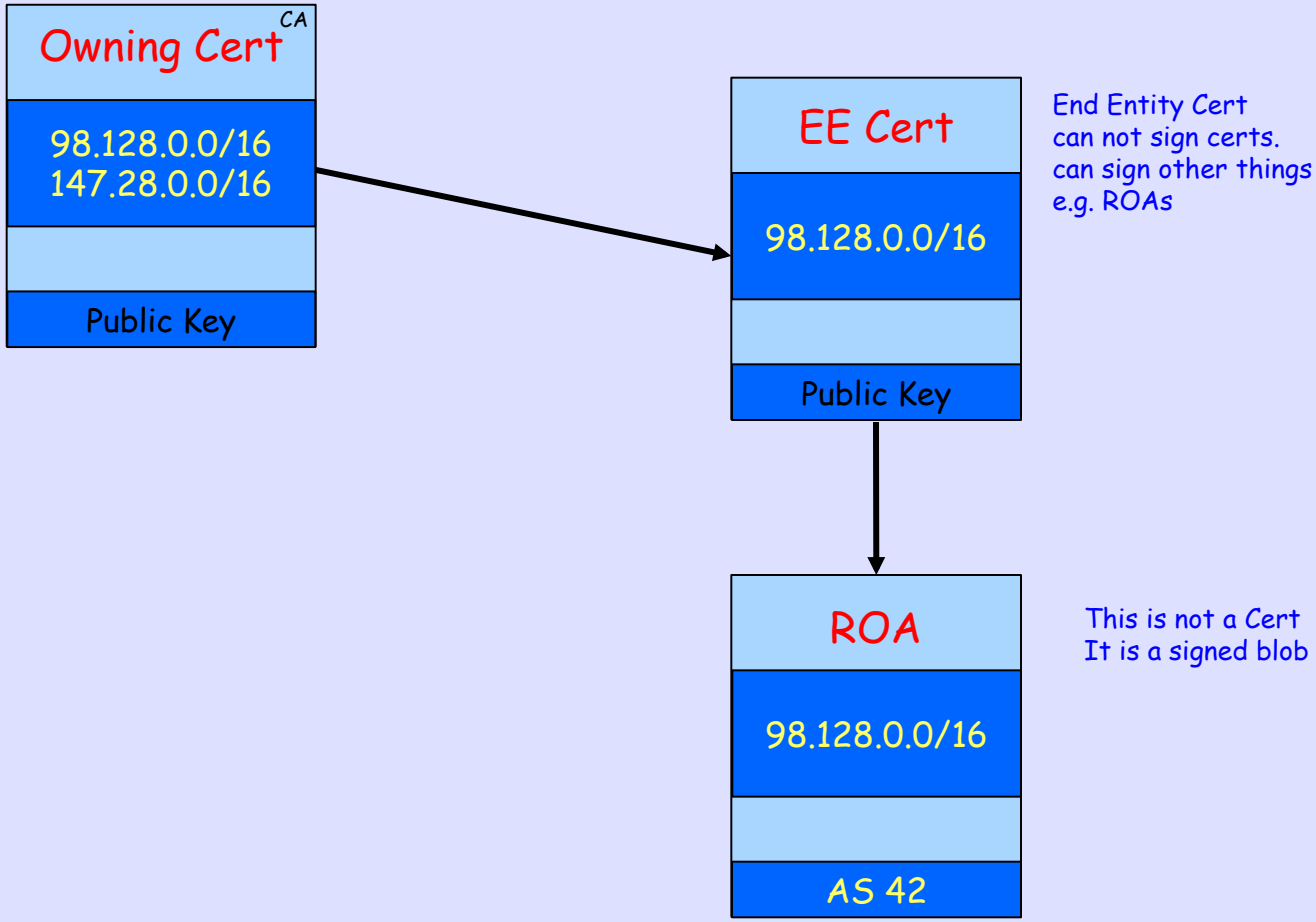


Certificate Hierarchy follows Allocation Hierarchy

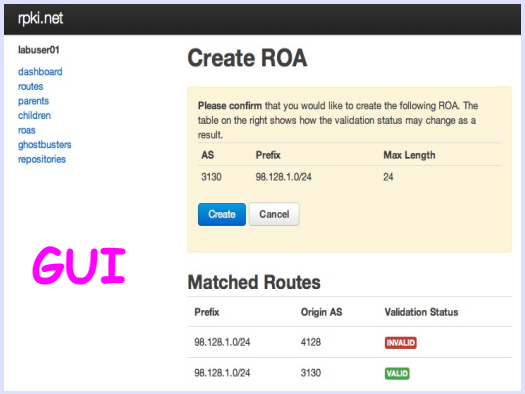


That's Who Owns It
but
Who May Route It?

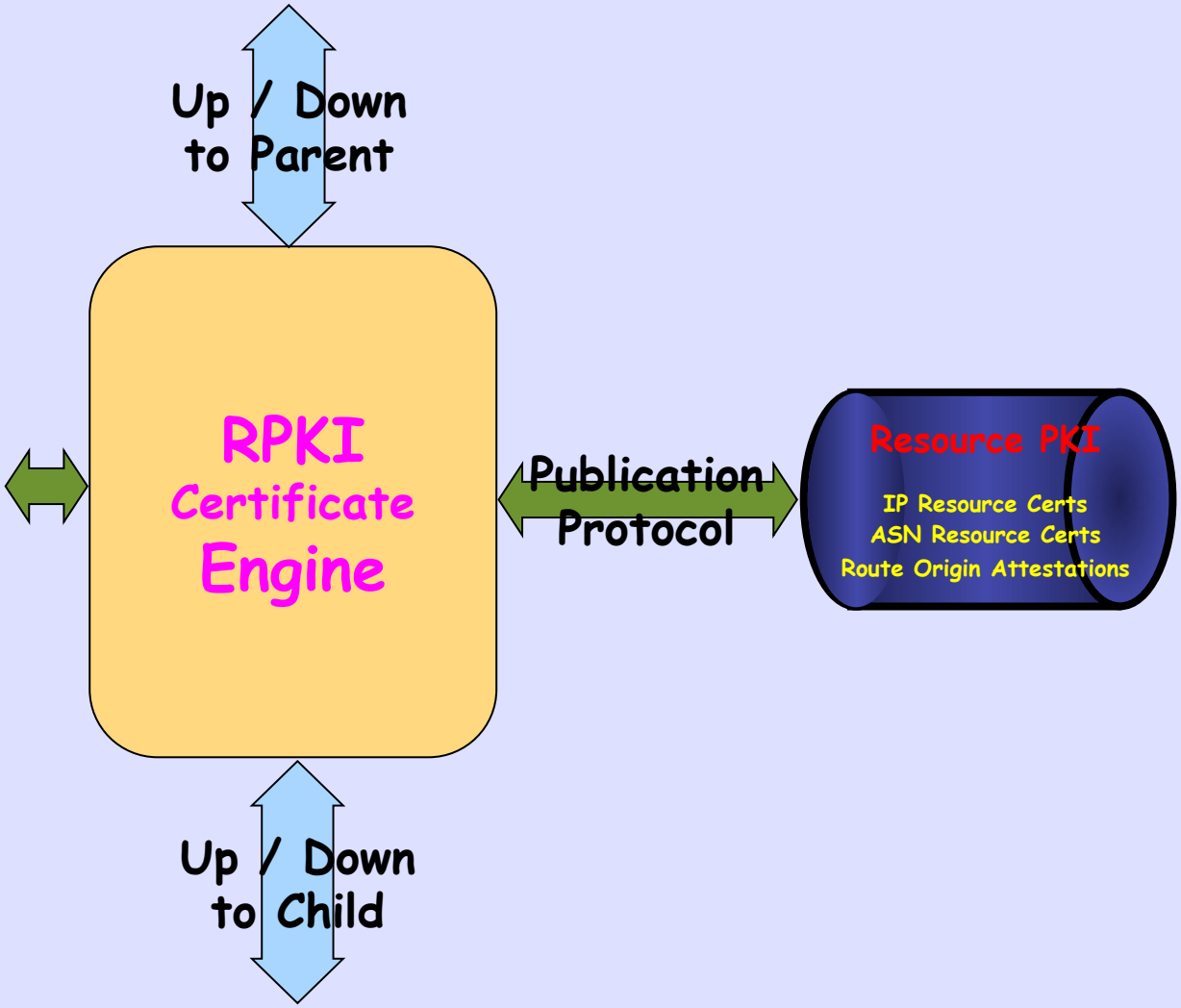
Route Origin Authorization (ROA)



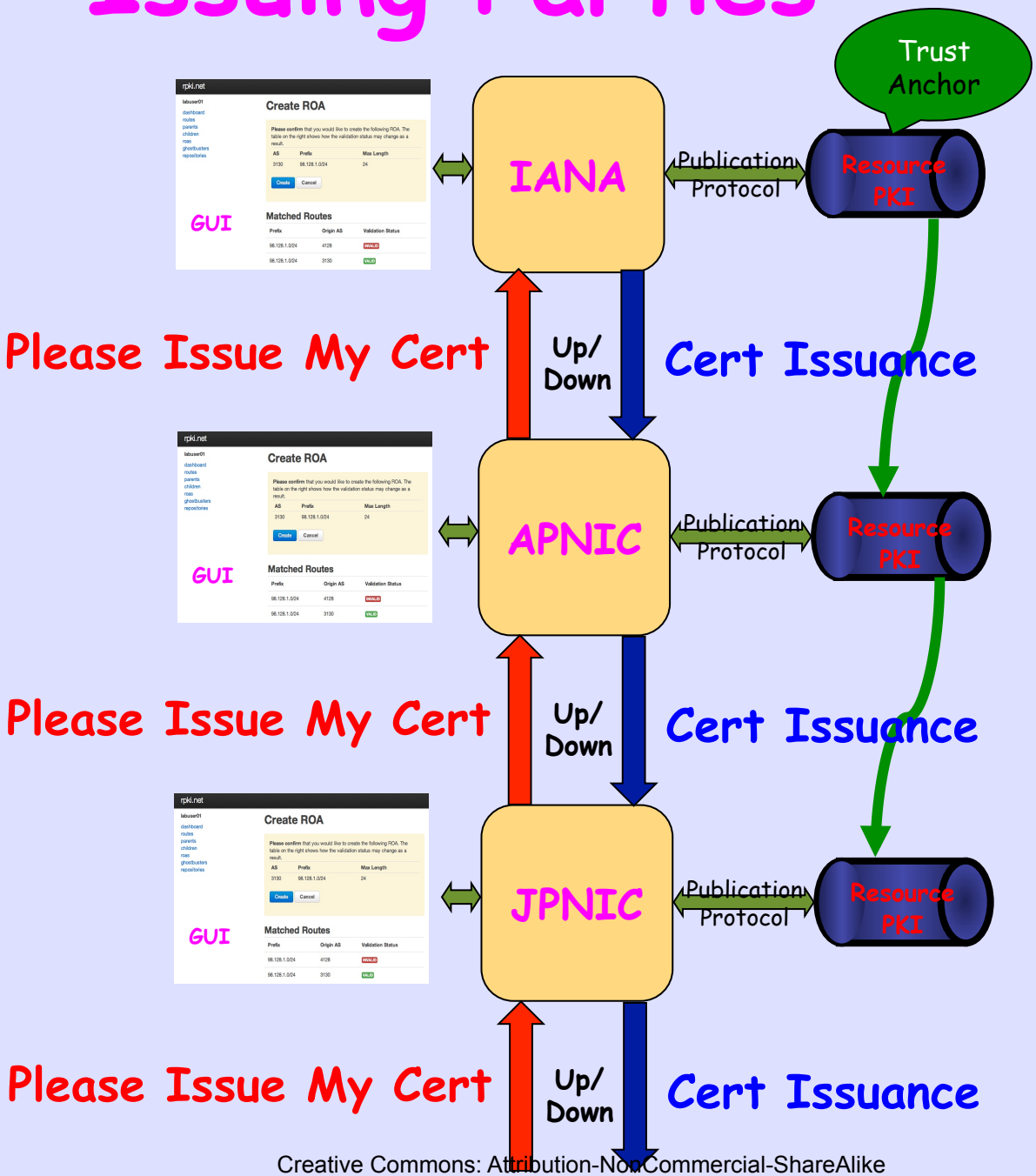
How RPKI is Generated



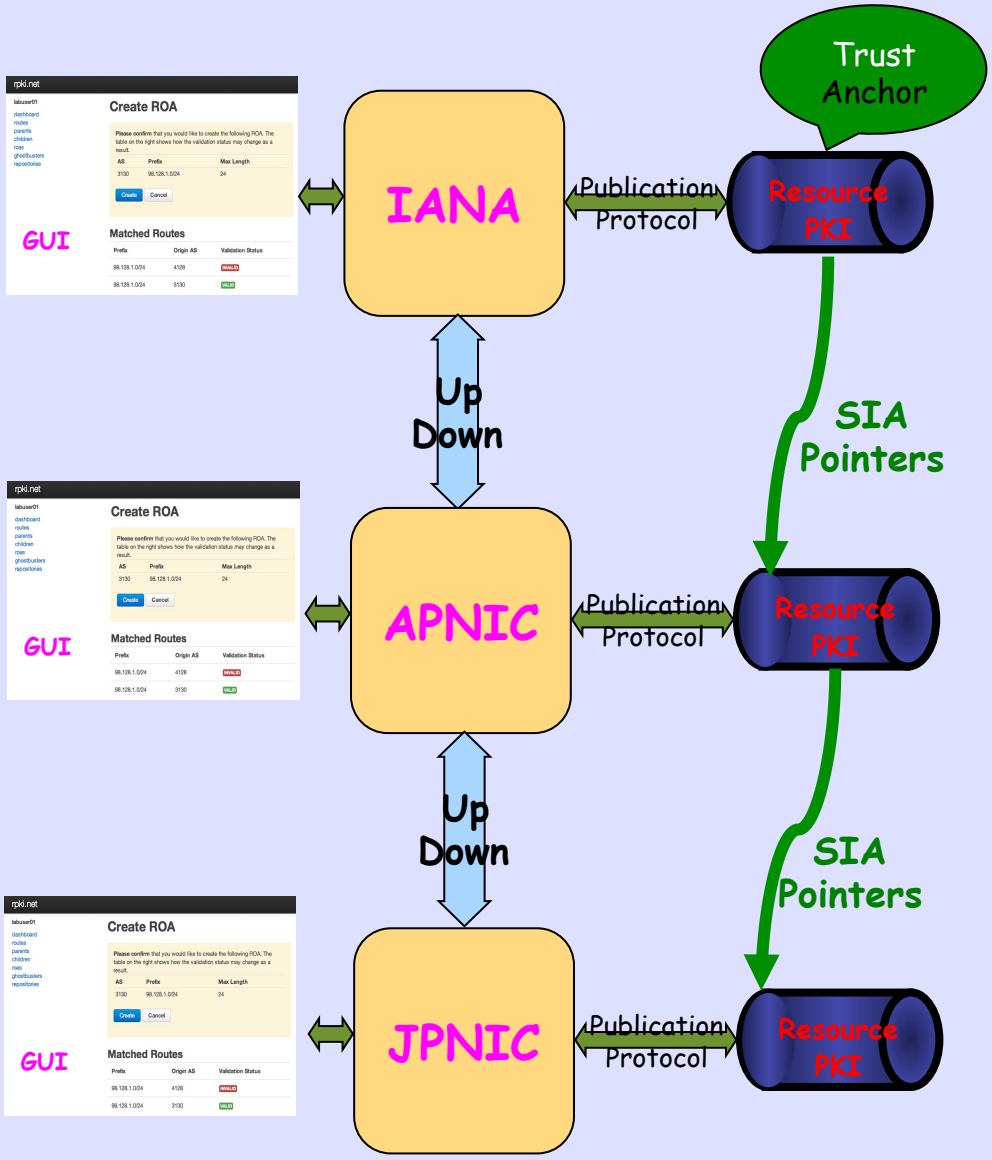
GUI



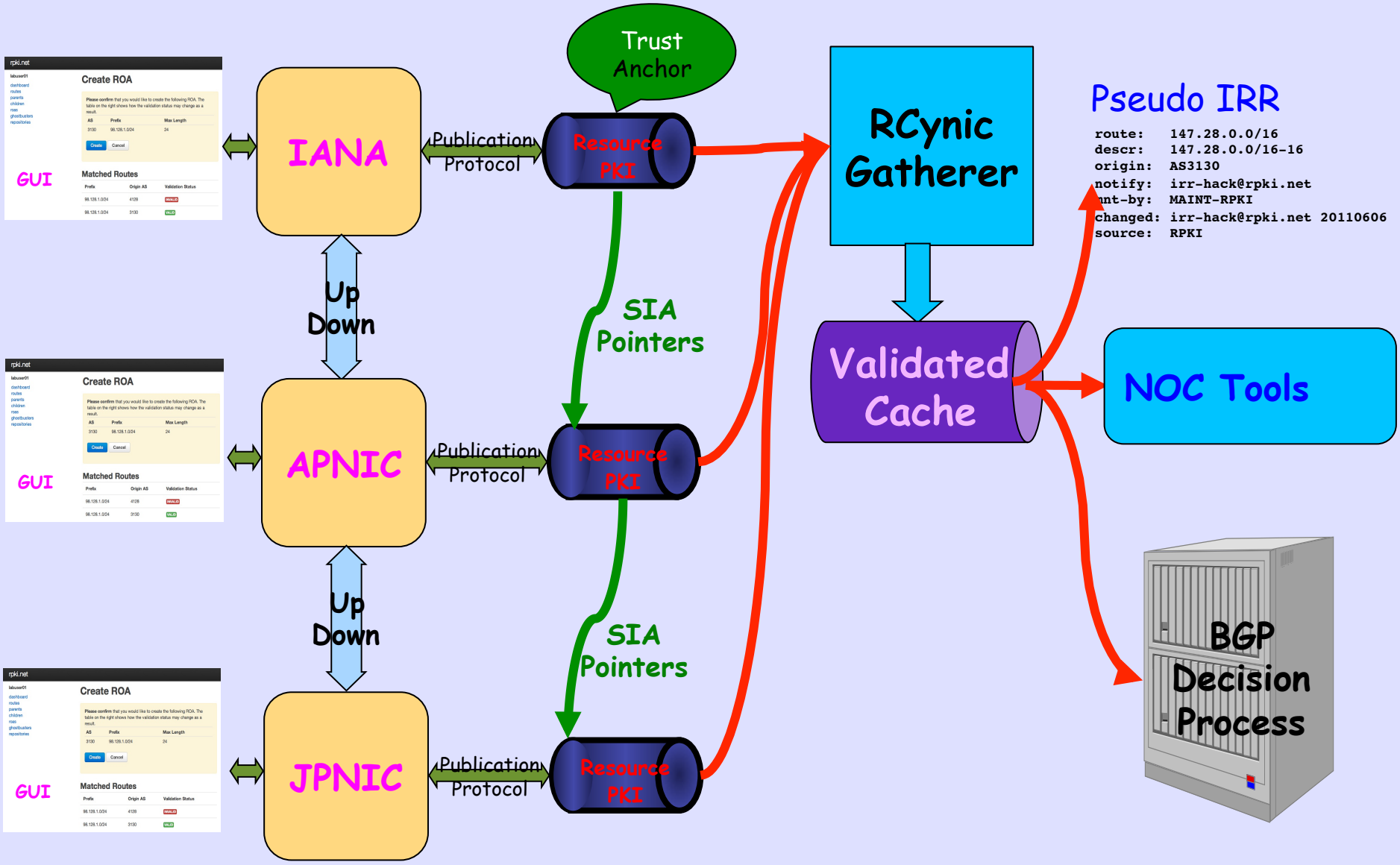
Issuing Parties



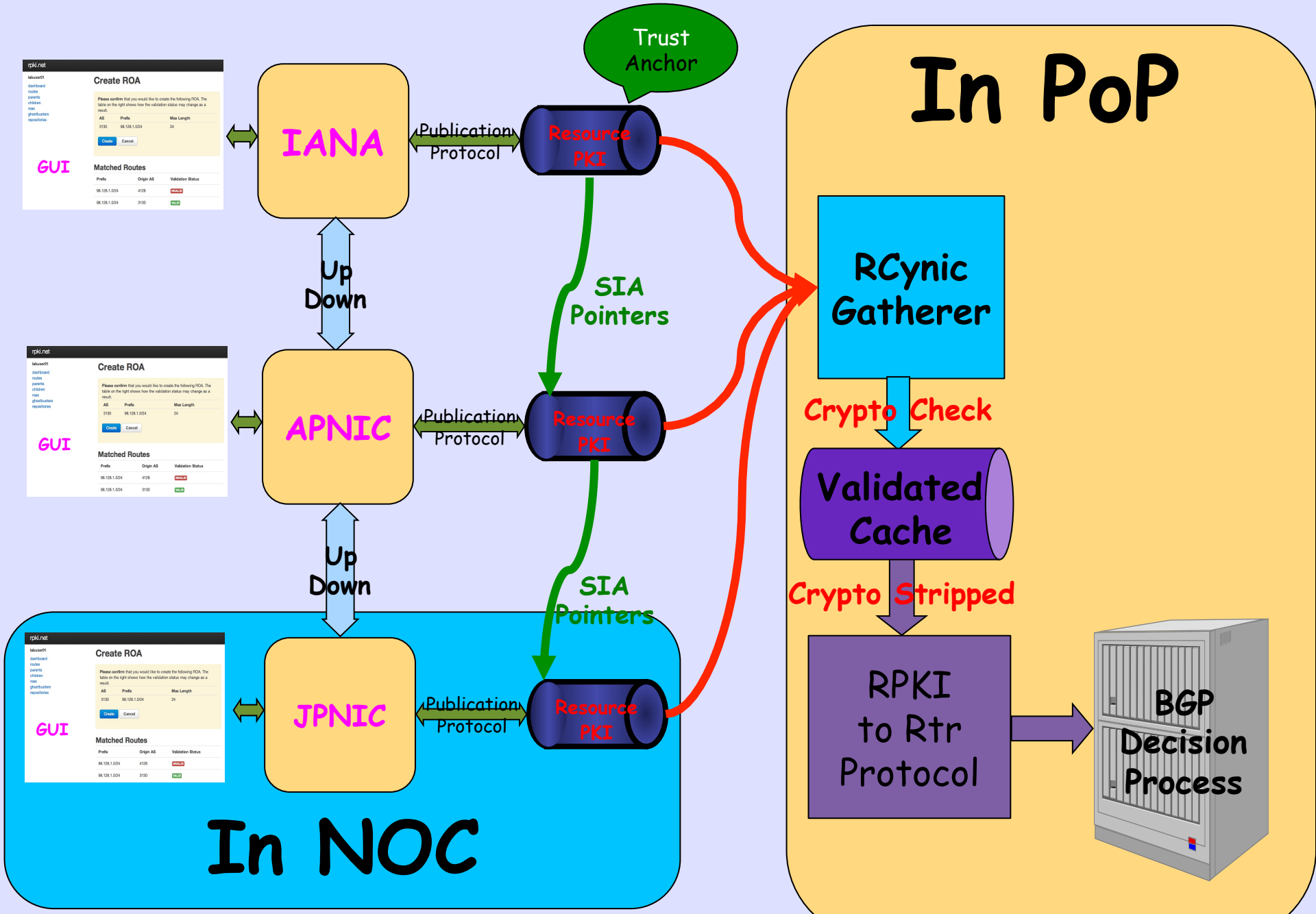
Issuing Parties



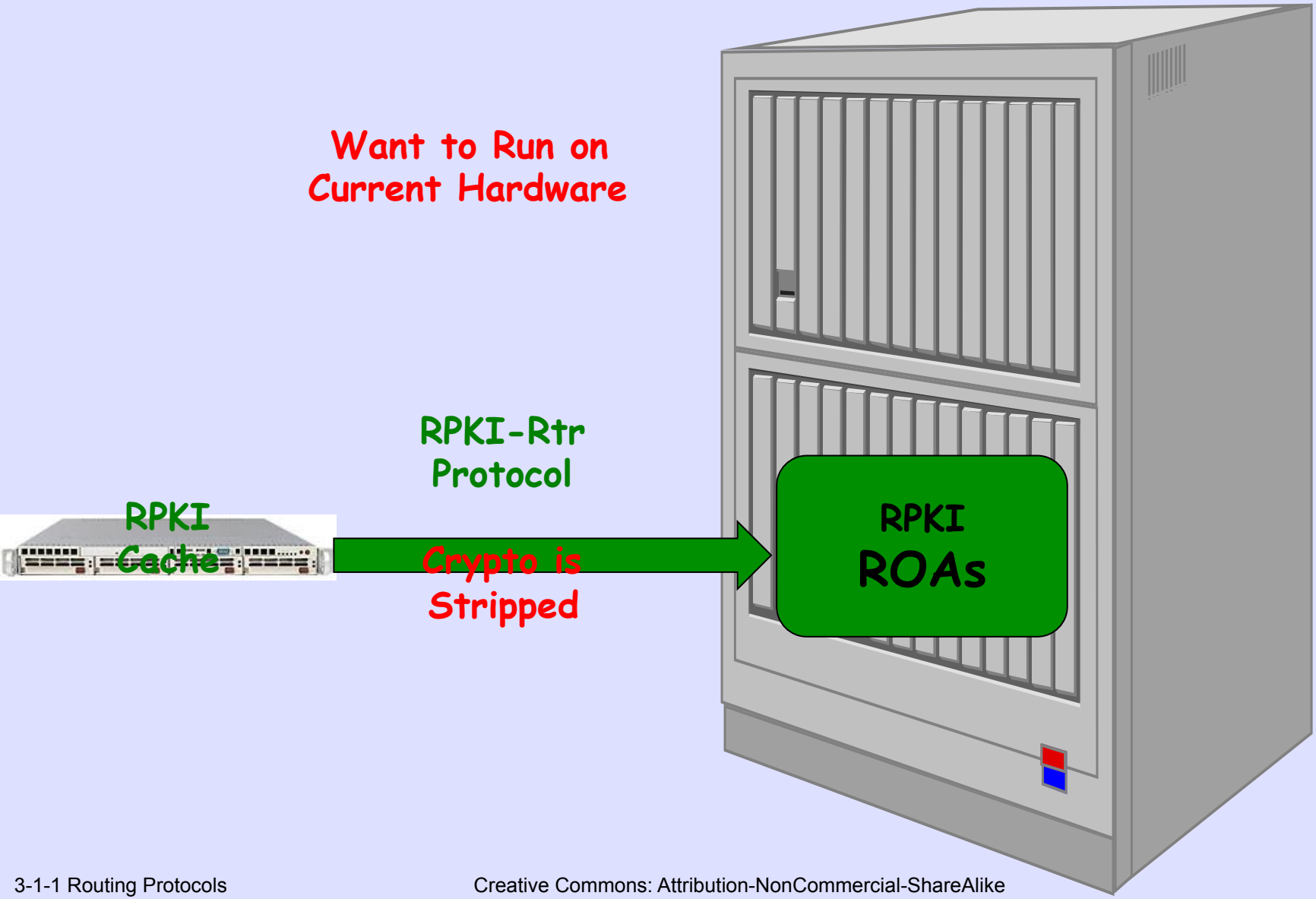
Issuing Parties Relying Parties



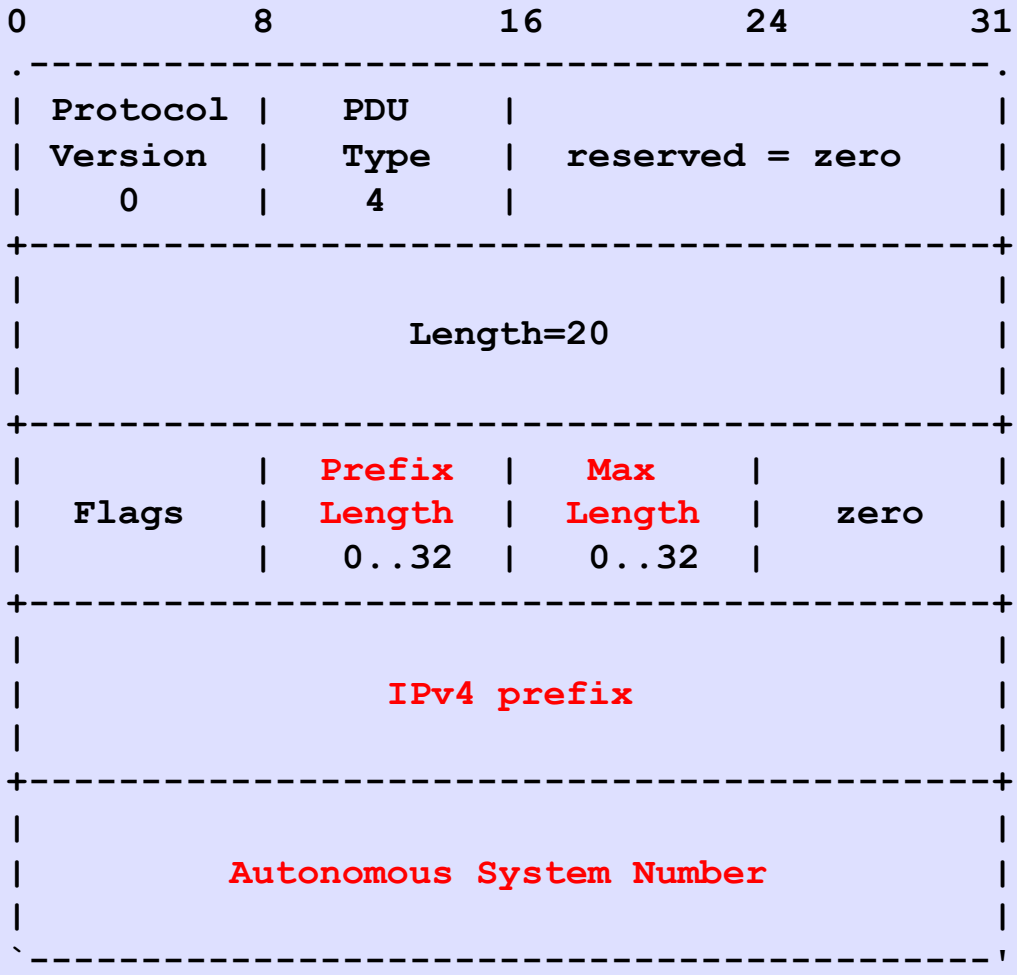
How Do ROAs Affect BGP Updates?



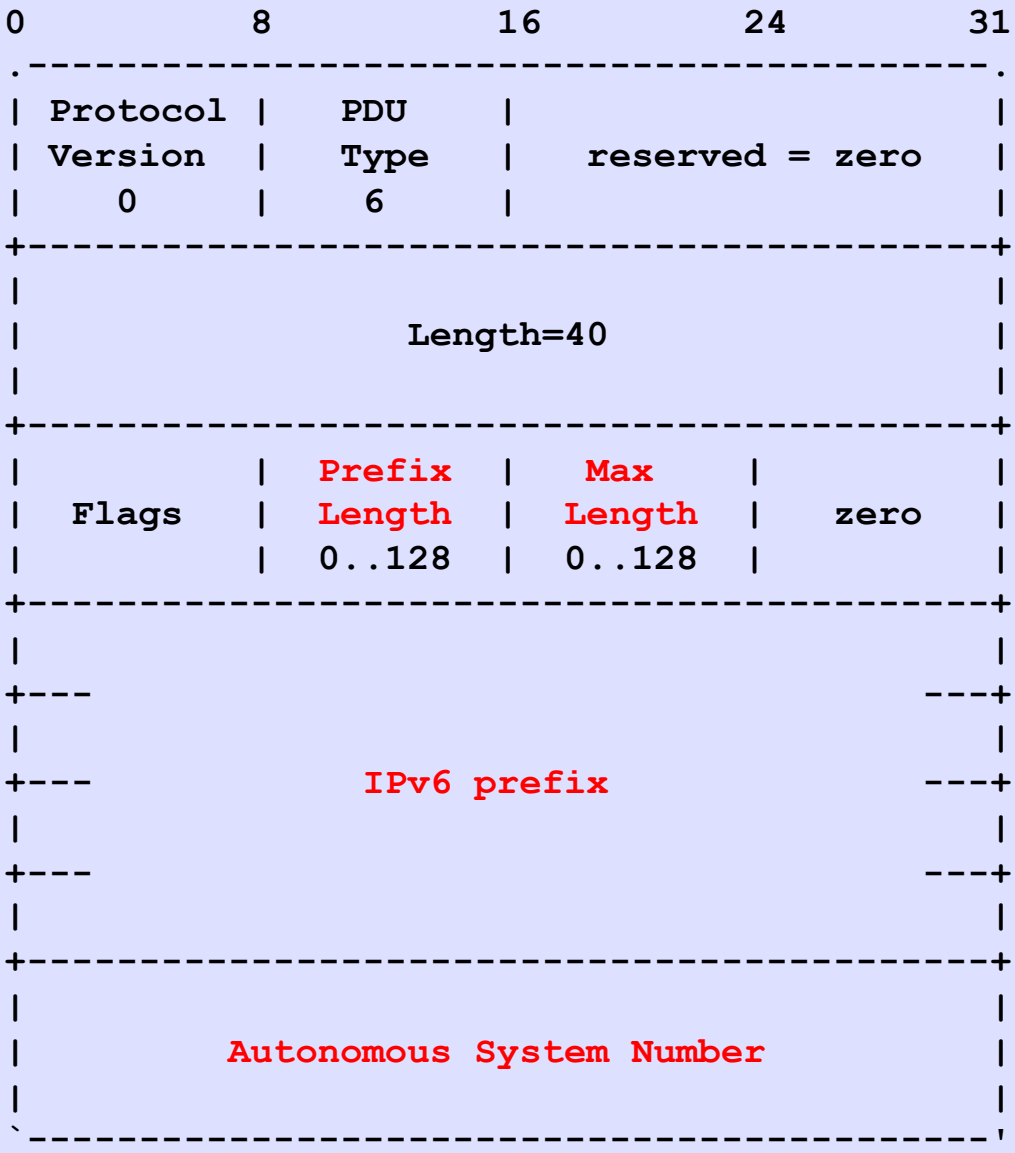
ROAs Become Router ROAs



IPv4 Prefix

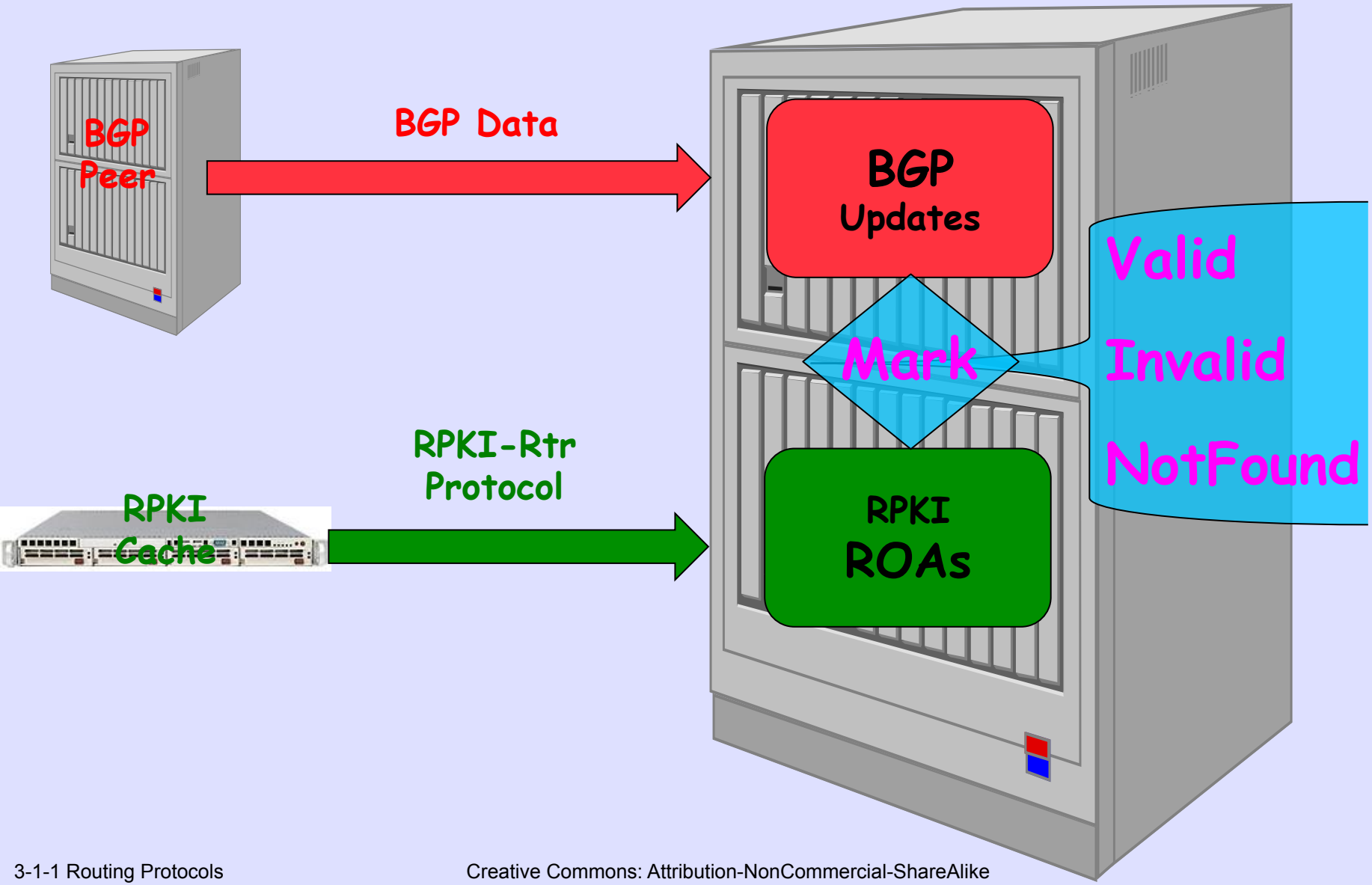


IPv6 Prefix



96 More Bits
No Magic

Marking BGP Updates



Result of Check

- **Valid** – A matching/covering ROA was found with a matching AS number
- **Invalid** – A covering ROA was found, but the AS number did not match, and there was no other matching one
- **NotFound** – No matching or covering ROA was found, same as today

Configure Router to Get ROAs

```
router bgp 651nn
 …
 bgp rpki server tcp 192.168.179.3 port 43779 refresh 60
 bgp rpki server tcp 147.28.0.84 port 93920 refresh 60
 …
```

Valid!

```
r0.sea#show bgp 192.158.248.0/24
BGP routing table entry for 192.158.248.0/24, version 3043542
Paths: (3 available, best #1, table default)
 6939 27318
    206.81.80.40 (metric 1) from 147.28.7.2 (147.28.7.2)
      Origin IGP, metric 319, localpref 100, valid, internal,
best
      Community: 3130:391
      path 0F6D8B74 RPKI State valid
 2914 4459 27318
    199.238.113.9 from 199.238.113.9 (129.250.0.19)
      Origin IGP, metric 43, localpref 100, valid, external
      Community: 2914:410 2914:1005 2914:3000 3130:380
      path 09AF35CC RPKI State valid
```

Invalid!

```
r0.sea#show bgp 198.180.150.0
BGP routing table entry for 198.180.150.0/24, version 2546236
Paths: (3 available, best #2, table default)
  Advertised to update-groups:
     2           5           6           8
  Refresh Epoch 1
  1239 3927
    144.232.9.61 (metric 11) from 147.28.7.2 (147.28.7.2)
      Origin IGP, metric 759, localpref 100, valid, internal
      Community: 3130:370
      path 1312CA90 RPKI State invalid
```

NotFound

```
r0.sea#show bgp 64.9.224.0
BGP routing table entry for 64.9.224.0/20, version 35201
Paths: (3 available, best #2, table default)
  Advertised to update-groups:
     2           5           6
  Refresh Epoch 1
  1239 3356 36492
    144.232.9.61 (metric 11) from 147.28.7.2 (147.28.7.2)
      Origin IGP, metric 4, localpref 100, valid, internal
      Community: 3130:370
      path 11861AA4 RPKI State not found
```

The Operator Tests the Mark and then Applies Local Policy

Fairly Secure

```
route-map validity-0
  match rpki valid
  set local-preference 100
route-map validity-1
  match rpki not-found
  set local-preference 50
! invalid is dropped
```

Paranoid

```
route-map validity-0
  match rpki valid
  set local-preference 110
! everything else dropped
```

Security Geek

```
route-map validity-0
  match rpki invalid
  set local-preference 110
! everything else dropped
```

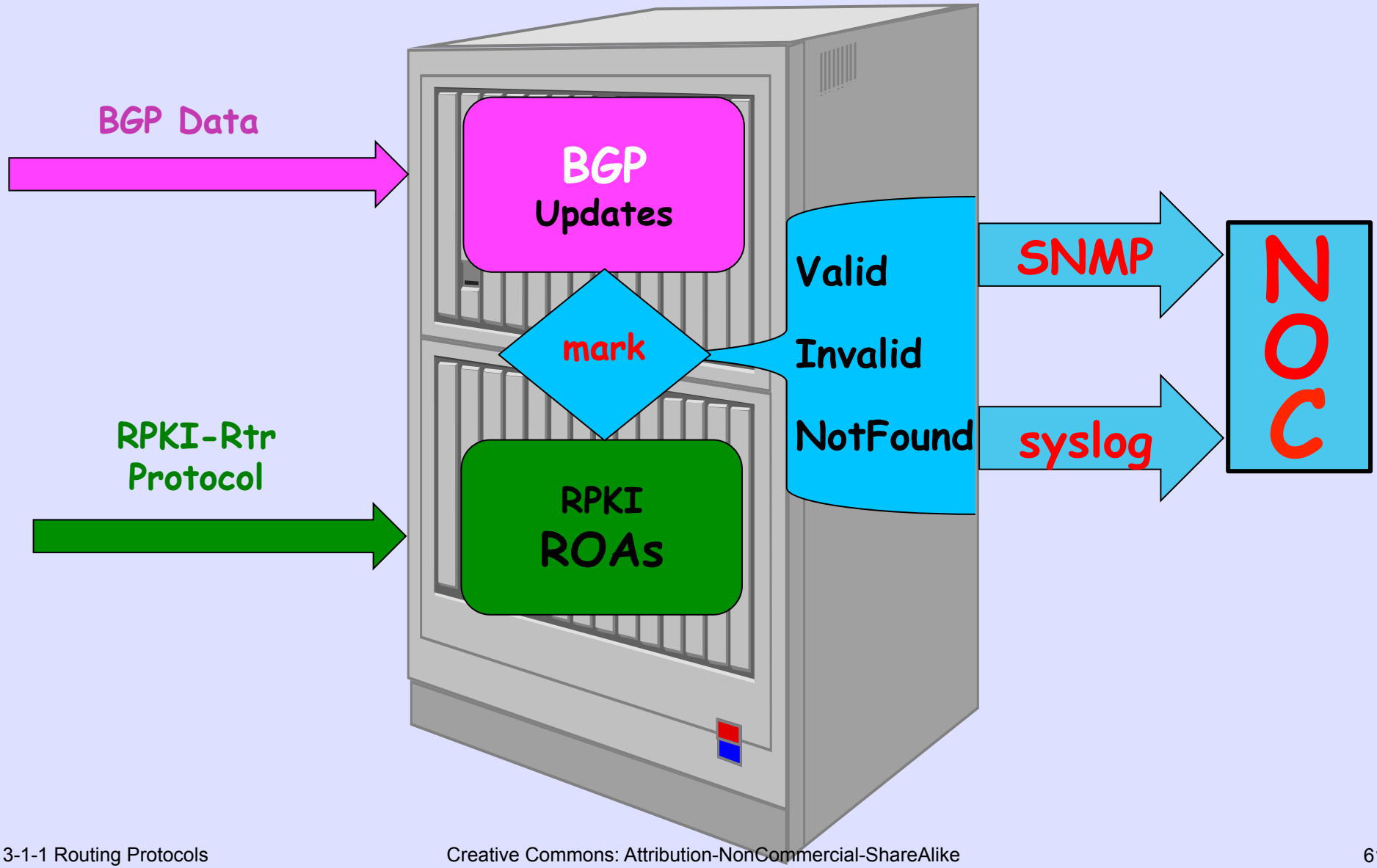
After AS-Path

```
route-map validity-0
 match rpki not-found
   set metric 100
route-map validity-1
   match rpki invalid
   set metric 150
route-map validity-2
   set metric 50
```

Set a Community

```
route-map validity-0
  match rpki valid
  set community 3130:400
route-map validity-1
  match rpki invalid
  set community 3130:200
route-map validity-2
  set community 3130:300
```

And it is All Monitored



But in the End, You Control Your Policy

"Announcements with Invalid origins SHOULD NOT be used, but MAY be used to meet special operational needs. In such circumstances, the announcement SHOULD have a lower preference than that given to Valid or NotFound."

-- draft-ietf-sidr-origin-ops

RPKI at the Registries

- RIPE seriously deployed with a few thousand LIRs and thousands of ROAs
- APNIC is operational and moving forward, moving to RIPE's GUI
- ARIN is doing their best to make RPKI deployment very hard
- LACNIC is deployed and has 100s of LIRs
- AFRINIC is deployed with O(25) LIRs

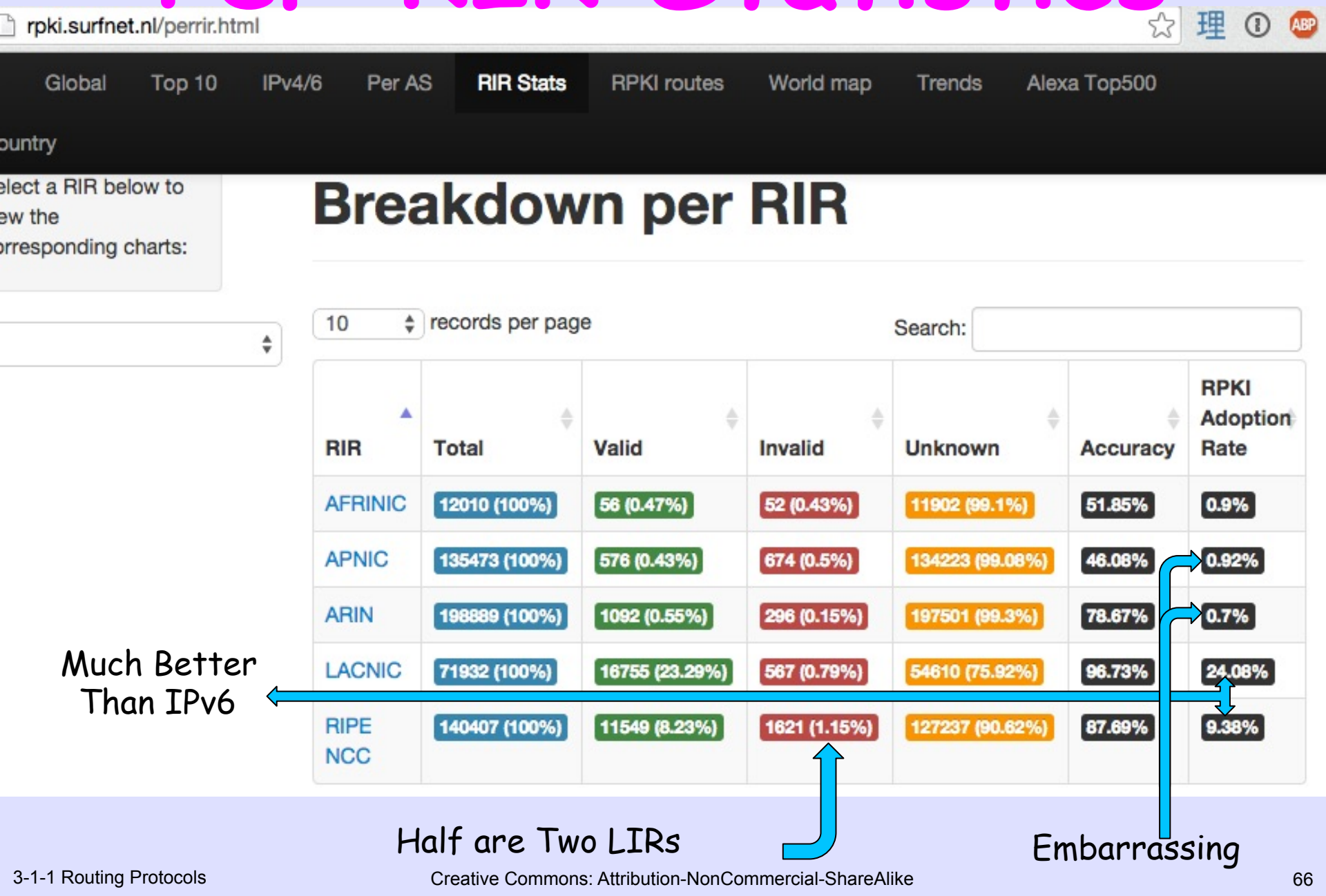
RIPE Progress

- Policy just passed to allow registration of legacy space without having to become a member or sign away all rights
- Policy just passed to allow registration of 40,000 PI allocations to end sites without having to become a full member
- And RIPE already had thousands of RPKI registrations

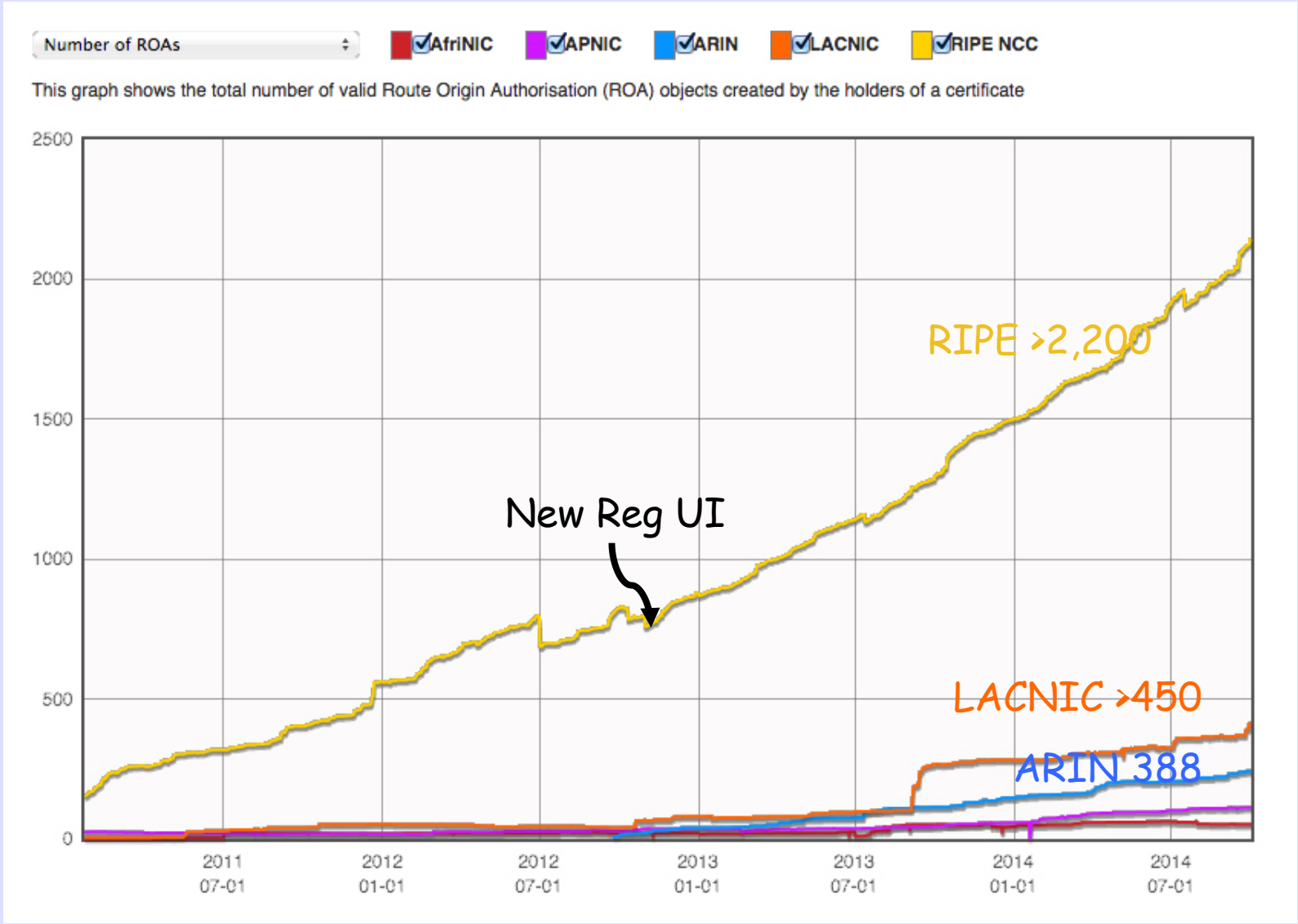
LACNIC / Ecuador

- LACNIC working with the Ecuador Internet Exchange
- All ISPs and almost all address space in Ecuador is certified and has ROAs
- All members of the exchange are using RPKI-Rtr protocol to get ROAs from a cache at the exchange
- Watching routers to see markings

Per-RIR Statistics



It's Embarrassing



Graph Courtesy RIPE/NCC

Router Origin Validation

- Cisco IOS – solid in 15.2
- Cisco IOS/XR – shipped in 4.3.2
- Juniper – shipped in 12.2
- AlcaLu – shipping

RPKI Implementations

- RIPE/NCC – CA (partial closed) & RP (partial open)
- APNIC – CA only – Closed Source
- RTRlib/Berlin – RP only – Open Source
- BBN – RP Only – Open Source
- Dragon Research – CA & RP – Open Source

Dragon Research Labs

- Open Source BSD License
- CA – Hosted and Delegated Models, GUI
- RP – RPKI-RTR, NOC Tools, IRR Gen
- FreeBSD, Ubuntu, Debian, … Packaged (docs still catching up)