# Nemecis: A tool to analyze the Internet Routing Registries

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# Problem

- We need cooperation between Autonomous Systems.

- Internet Routing Registries (IRR) is an attempt
- IRR: text based repository of BGP related policy
- Problem: IRR have not reached their full potential

- has not been explored
- its accuracy has not been quantified
- is very complicated described in RPSL

# Contribution: NEMECIS

- We provide a framework for BGP policy analysis

- We quantify the accuracy of the IRR
  - Check the policies for correctness / freshness
  - This was a long term goal of RIPE

- We develop a tool to analyze IRR data
  - We use a relational database to store the policies
  - Web based front-end for the database

# The Rest of this talk

- IRR and RPSL

- Key concepts of Nemecis

- Quality of Information in IRR

- Nemecis web-based interface

- Conclusions

# How is policy described in RPSL?

- Policy description resembles BGP filtering

- Routes:  from AS1 accept 138.23.0.0/16

- Regular expressions on the AS Path: from AS1 accept <^AS1+ AS2*>

- Communities: from AS1 accept community(xxx:yyy)

- RPSL provides high level structures to group routes

- AS numbers (AS1): all routes the AS registers

- AS-SET: AS numbers and other AS-SETS

- ROUTE-SET: routes and other ROUTE_SETS

# Example of An RPSL Description

```
route:          138.23.0.0/16
origin:         AS4
```
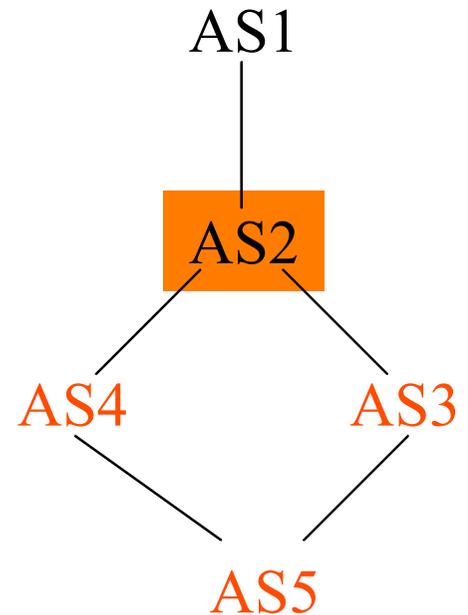Registered/Maintained by AS4

```
as-set:         AS3-ISP
members:        AS3, AS5
```
Registered/Maintained by AS3

```
as-set:         AS2-ISP
members:        AS2, AS3-ISP, AS4
```

```
aut-num:        AS2
import:         from AS1 accept ANY
import:         from AS3 accept AS3-ISP
import:         from AS4 accept <^AS4+AS5*$>
export:         to AS3 announce ANY
export:         to AS4 announce ANY
export:         to AS1 announce AS2-ISP
```
Registered/Maintained by AS2

AS1

AS2

AS4        AS3

AS5

# ... things can become scary...

```
aut-num:      AS2
import: {

      from AS-ANY action pref=10;
          accept community.contains(1:1);
      from AS-ANY action pref=0; accept ANY;
    } refine {
     from AS2:AS-CUSTOMERS
     accept (PeerAS OR AS2:AS-CUSTOMER:PeerAS)
     AND <^PeerAS+ AS2:AS-CUSTOMER:PeerAS*$>
    }
```

AS1

AS2

AS4          AS3

AS5
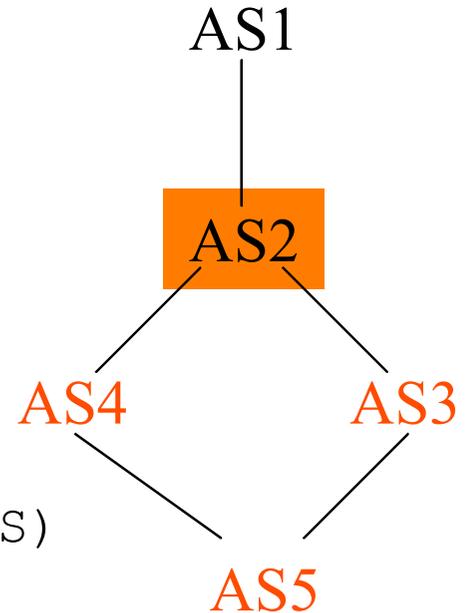
- Policies can be thousands of lines long

- Sets can contain tens of thousand of members

- Inconsistent / out of date policy

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# Nemecis: Three main phases

■■ Create the database:

○ Parse RPSL policy text, put data in tables

■■ Correlate import and export policies

○ Export = what I create + what I import
○ For each export find where it comes from
○ Find at the level of a link: what I do with incoming data

■■ Infer business relations: from link-level model

○ Examine export policies of two neighbors
○ If not enough or incomplete, use import policies

■■ Deal with incomplete and inaccurate data

# Link Level Export Matrix

| Links | 1 | ... | i | j |
|-------|---|-----|---|---|
| 1 | x | | | |
| ... | | x | | |
| i | | | x | export |
| j | | | export | x |

Relation Matrix of an AS: which link I export to which other AS

# Hierarchy in sets

AS4-ISP

AS4　　　　AS4:CUST

AS2　AS3

AS5-ISP

AS5　　AS2

AS6

AS5　　AS4

AS2　　AS3
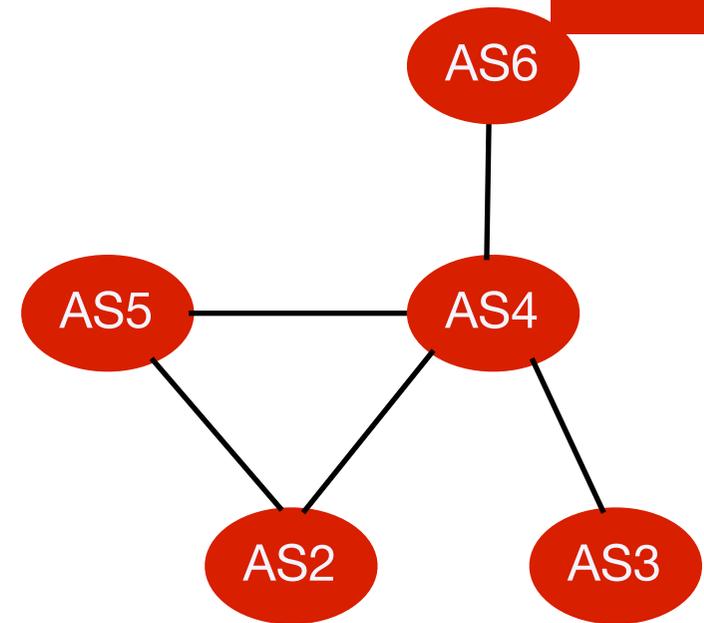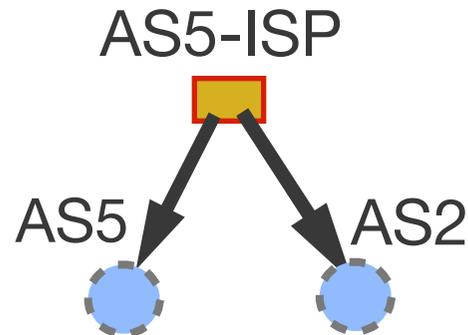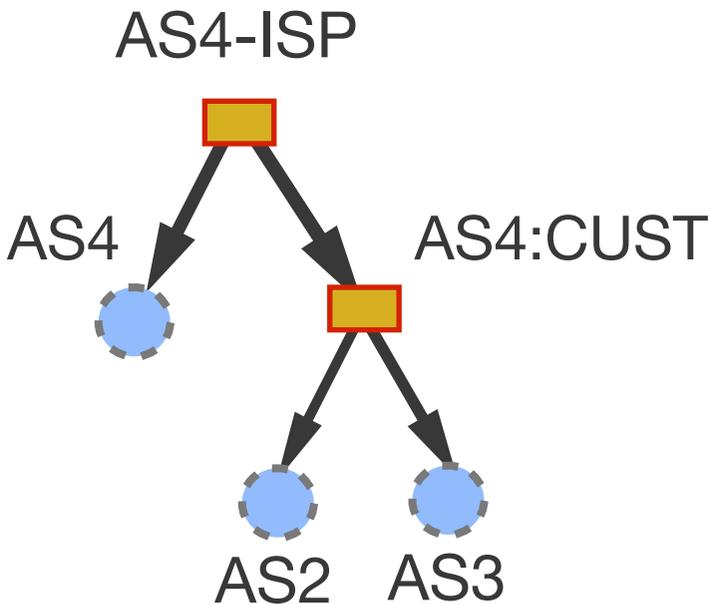
- Our algorithm work wells when ASes maintain the hierarchy in the sets.

- Medium to large ASes (connectivity) can have more than one path to an AS. Figuring out if their policy is correct if they don't maintain the hierarchy is 'impossible'.

- For example Level3 has one huge route-set.

# Policy 'must' be symmetric

```
aut-num:     AS1
import:      from AS2 accept AS2
import:      from AS3 accept AS3-ISP
       ...
export:      to AS2 announce ANY
export:      to AS3 announce AS1-ISP
```
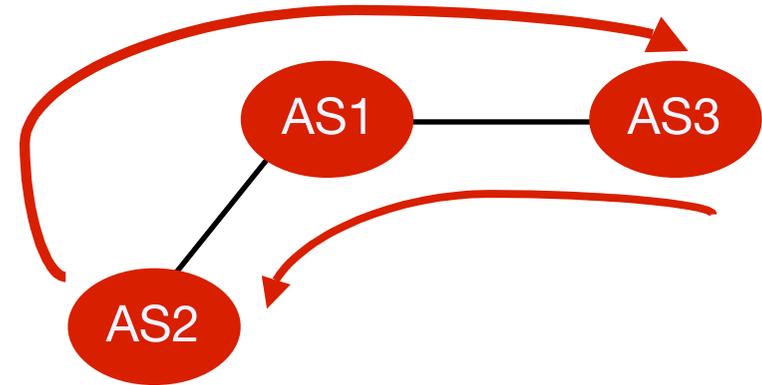


- A big problem is the difference in time between the aut-num object and the sets that it uses. Differences of several months are not uncommon.

- Consider the scenario that AS2 is no more a customer of AS1. AS1 updates only it's as-set, but not it's aut-num record. This problem will be undetected if we don't 'enforce' symmetry.

- Of course we might classify correct policies as incorrect.

# 4 Simple Business Relations
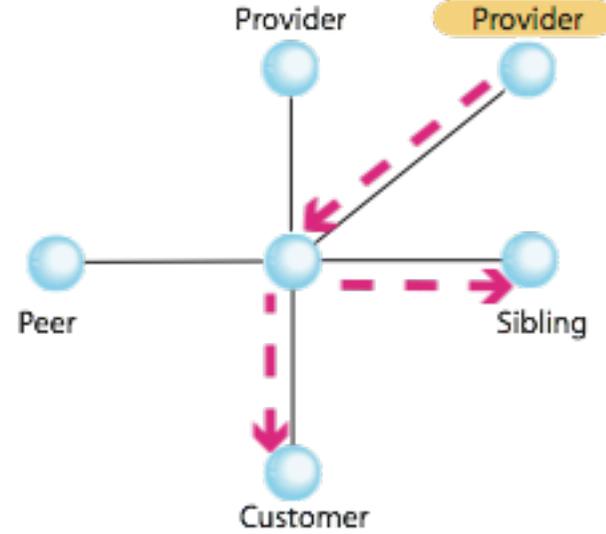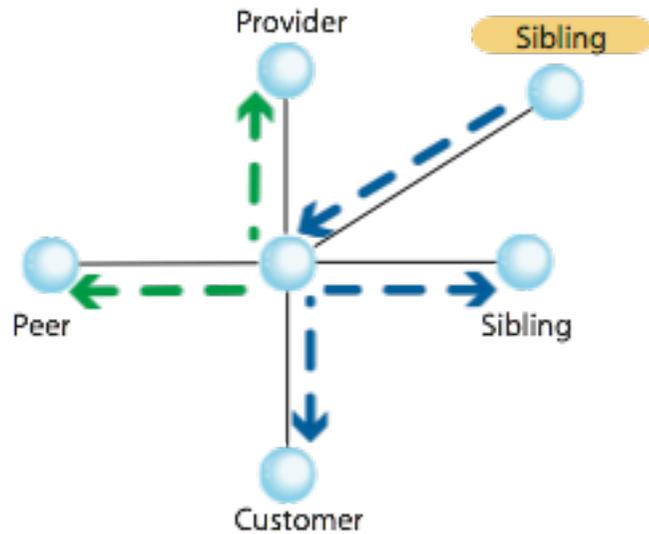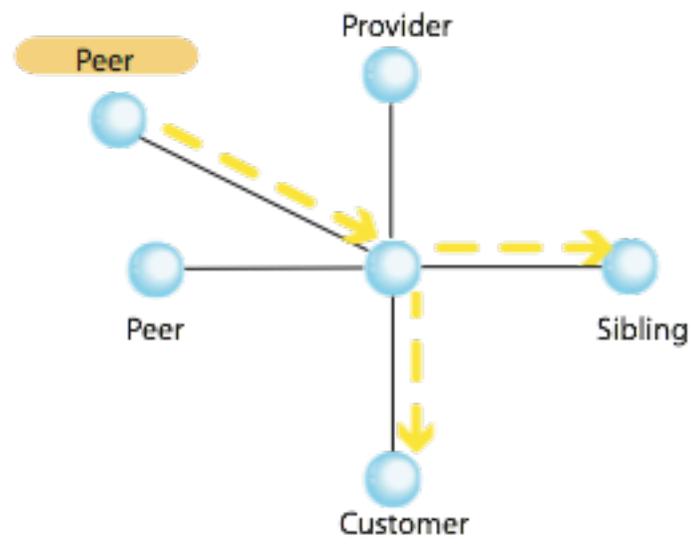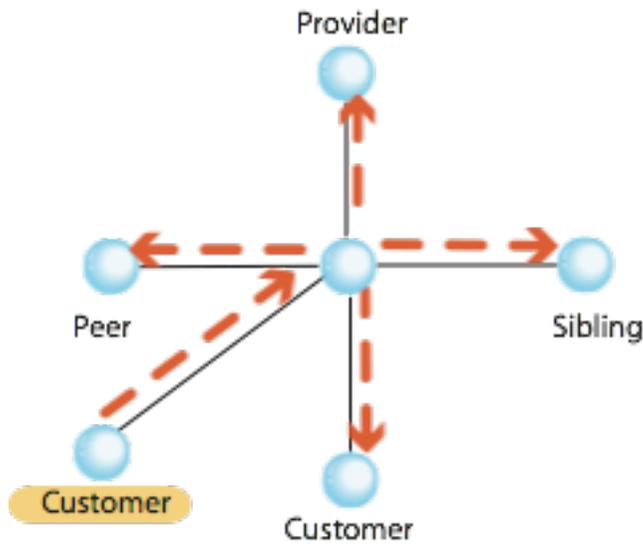


Business relations can be grouped by the export filters

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# How many ASes register their policy?

**ASes Registering Policy**

- 6,362 (Ripe)
- 2,066 (Radb)
- 2,058 (Apnic)
- 1,061 (Rest)

**Average Degree**

- 12 (Ripe)
- 6 (Radb)
- 3 (Apnic)
- 6 (Rest)
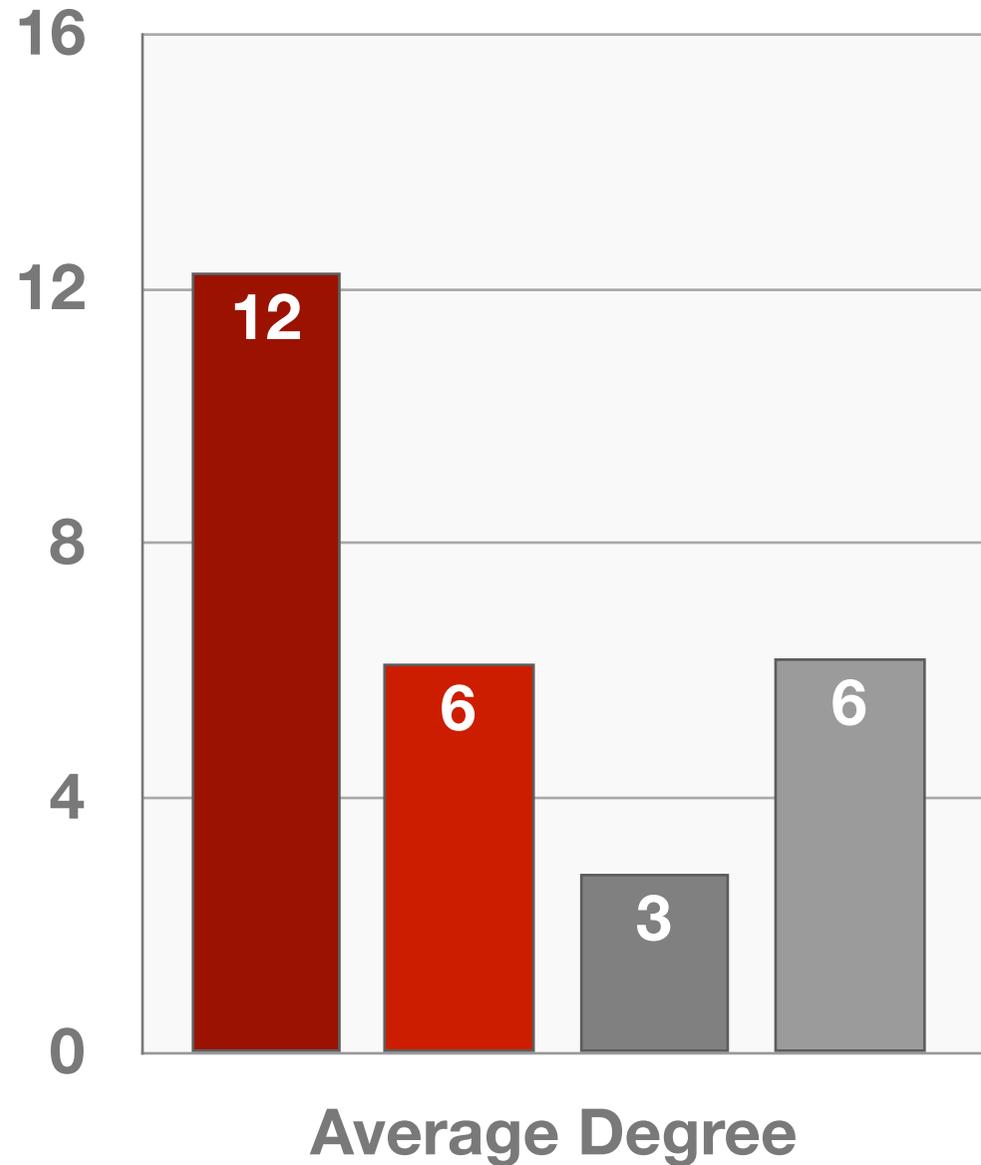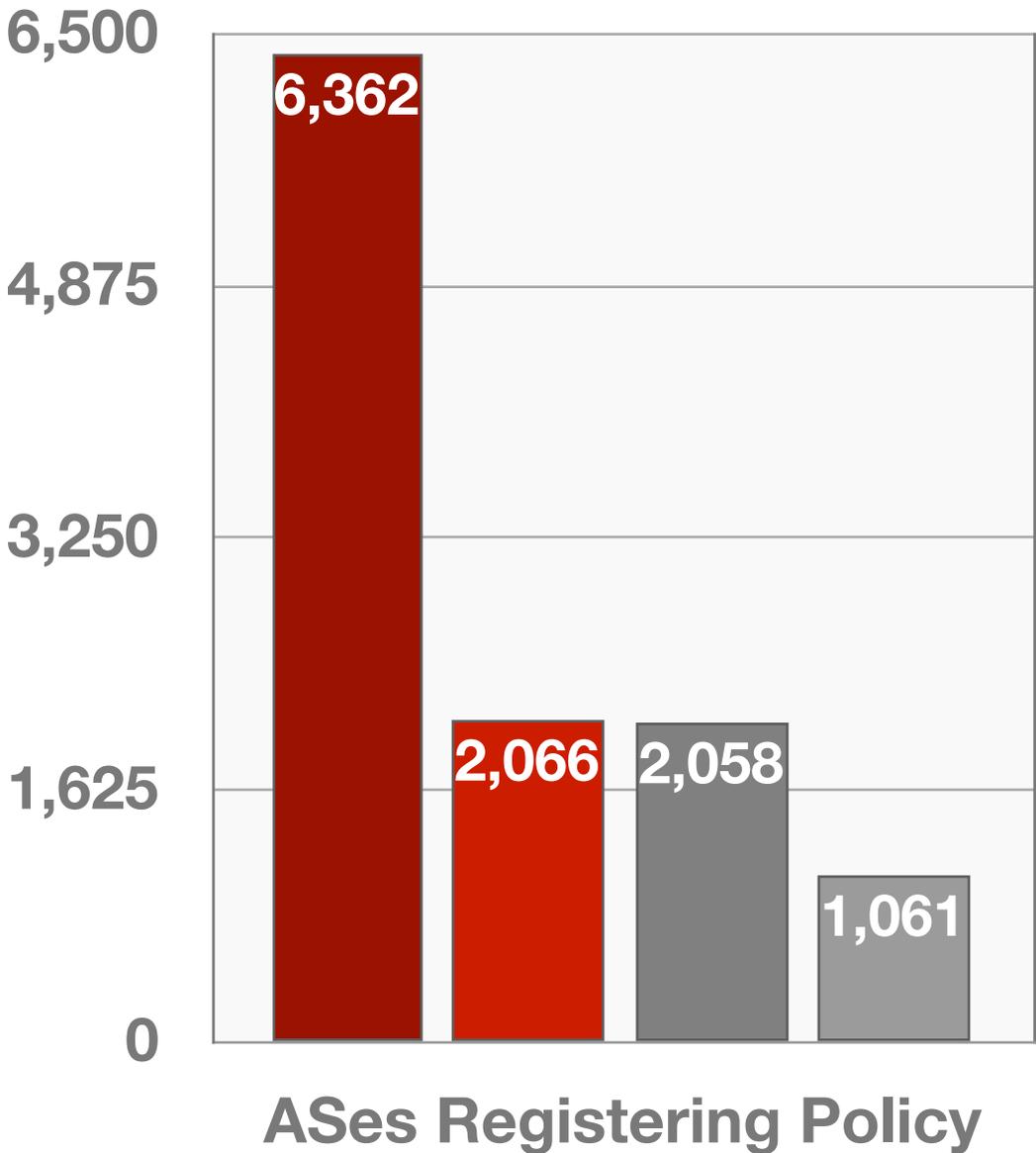
# Do both peers register "each other"?

**Ripe**   **Radb**   **Apnic**   **Rest**



**Both directions exist (%)**

IRR

```
Policy of AS1:
from AS2 import B
to AS2 export A

Policy of AS2:
from AS1 import A
to AS1 export B
```

# Do they use the same filter?



Legend: Ripe, Radb, Apnic, Rest

Bar chart — Same filter used(%):
- Ripe: 49
- Radb: 40
- Apnic: 38
- Rest: 56
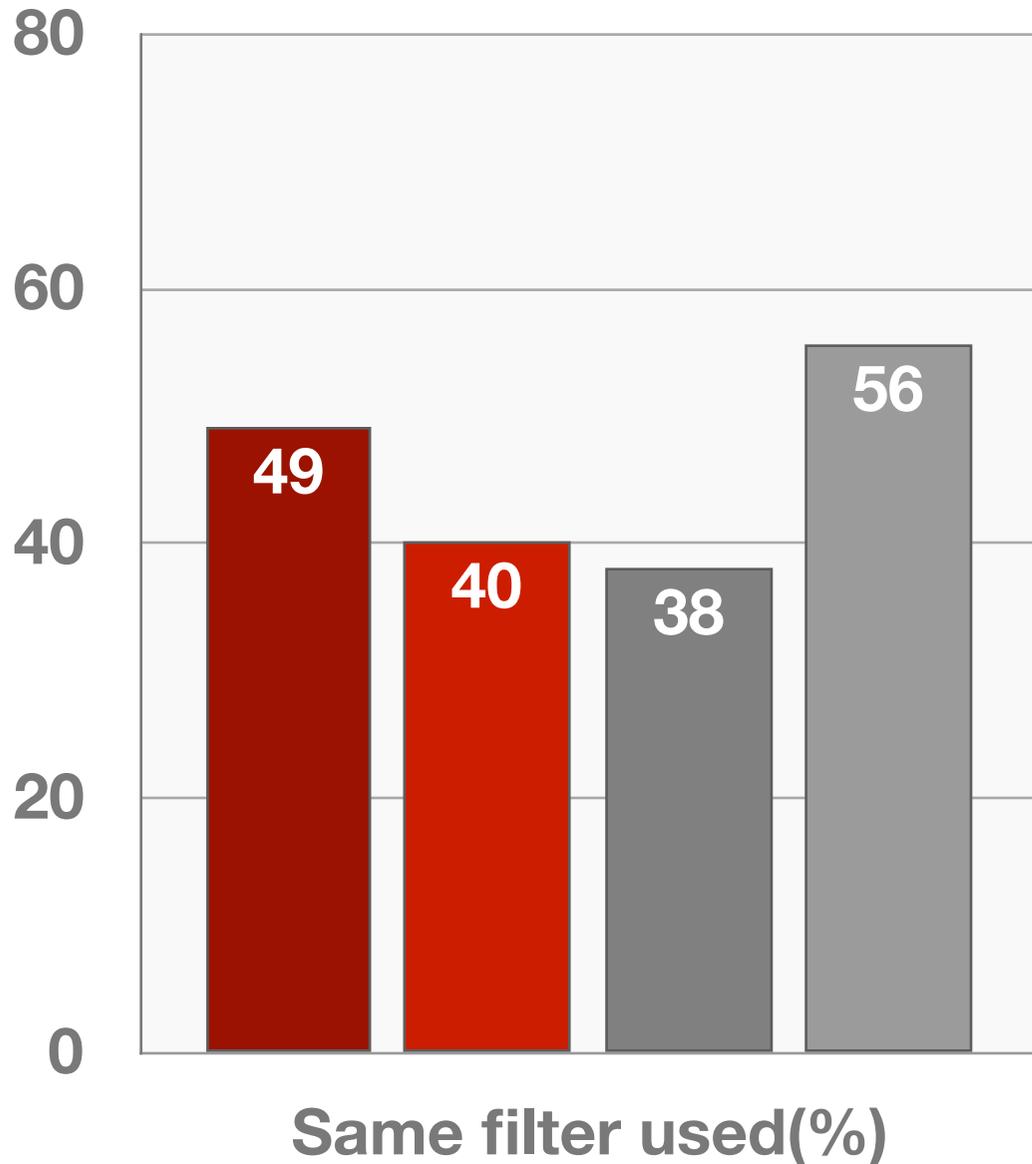
Examples of same filter

Policy of AS1:
from AS2 import B
to AS2 export A

Policy of AS2:
from AS1 import A
to AS1 export B

# Tests for consistency of IRR

- Policy based tests (correctness)

  - import-export consistency

  - Link-Level policy is symmetric

- BGP based tests (freshness)

  - All peers of an AS, as found in BGP, must be registered in IRR.

  - The high-level policy of an AS should be the same in both BGP and in IRR (e.g. Provider to Customer).
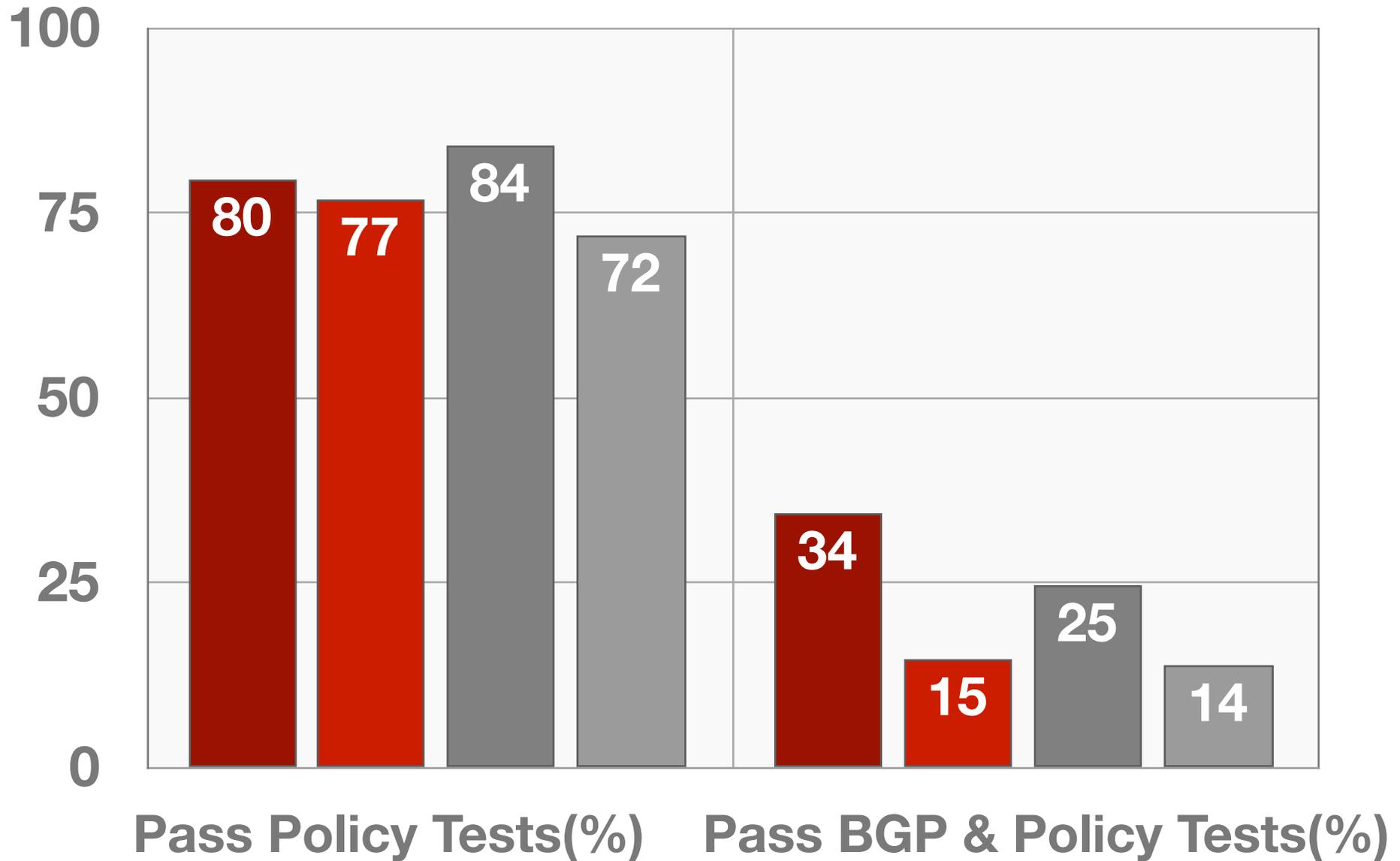
# The Rest of this talk
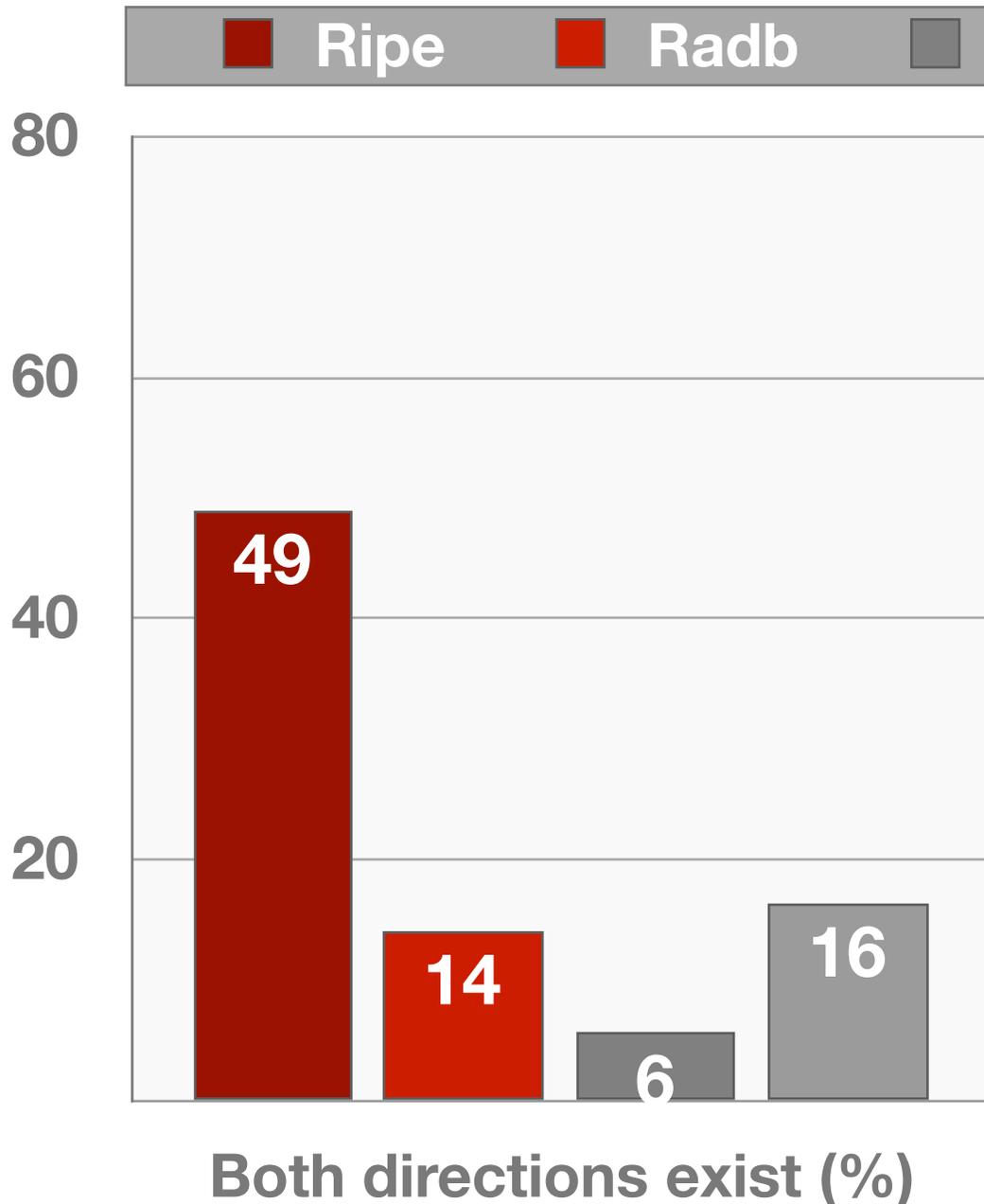
- IRR and RPSL

- Key concepts of Nemecis

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# Welcome to Nemecis

Welcome to the Nemecis project website. The goal of the Nemecis project is to develop the necessary frameworks / tools to analyze and improve the Internet Routing Registries(IRR). In the current implementation of the IRR, the policy information is stored as text and there are no consistency tests built in the registries. We have developed a framework to analyze the registered policy and check for their correctness and freshness. In this website you can query our database and check possible errors we have found in the policy registrations.

You can find more information in our paper 🌐Analyzing BGP Policies: Methodology and Tool

Please send me your comments at ✉️siganos@cs.ucr.edu.

# Browse the Registries (May 01 2004).

You can browse the Registries . ⬅️

# Retrieve the policy of an Autonomous System(May 01 2004).

For example use **AS702** (UUNET Europe) or **AS3303** (SWISSCOM).

Note that an AS might have more that one aut-num record.
I will return the **newest** one.

[                    ]  Get the Policy  ⬅️

http://ira.cs.ucr.edu:8080/Nemecis

# Nemecis

## 📁 Registries

▲ Up one level

| registry ▲ | number of ases |
|---|---|
| 📁 RIPE | 8232 |
| 📁 RADB | 2279 |
| 📁 APNIC | 2185 |
| 📁 VERIO | 357 |
| 📁 ARIN | 288 |
| 📁 ALTDB | 142 |
| 📁 CW | 135 |
| 📁 EPOCH | 104 |
| 📁 DODNIC | 92 |
| 📁 KT | 76 |
| 📁 LEVEL3 | 68 |
| 📁 BELL | 62 |
| 📁 AOLTW | 21 |
| 📁 JPIRR | 13 |
| 📁 SINET | 12 |
| 📁 CHTR | 11 |
| 📁 OTTIX | 9 |

# Nemecis

| view | missing objects |

state: visib

## 📁 RIPE

▲ Up one level

[1] 2 3 4 ... 83                                        next 100 items »

| as number ▲ | as name | number of peers | last modified |
|---|---|---|---|
| 📁 AS3356 | LEVEL3 | 1059 | 2004/04/30 |
| 📁 AS702 | AS702 | 833 | 2004/04/30 |
| 📁 AS8220 | COLT | 639 | 2004/04/27 |
| 📁 AS4513 | AS-GLOBIX | 554 | 2004/02/16 |
| 📁 AS4589 | EASYNET | 546 | 2004/04/19 |
| 📁 AS6730 | SUNRISE | 533 | 2004/04/29 |
| 📁 AS2686 | ATGS-MMD-AS | 525 | 2004/04/13 |
| 📁 AS3303 | SWISSCOM | 518 | 2004/04/30 |
| 📁 AS13237 | LAMBDANET-AS | 513 | 2004/04/23 |
| 📁 AS1257 | SWIPNET | 434 | 2004/04/26 |
| 📁 AS6728 | NILDRAM | 429 | 2004/04/23 |
| 📁 AS6805 | TDDE-ASN1 | 393 | 2004/04/02 |
| 📁 AS6830 | AS6830 | 384 | 2004/01/28 |
| 📁 AS15412 | FLAG-AS | 362 | 2004/04/27 |
| 📁 AS6667 | FUNET-FINLAND | 360 | 2004/04/27 |

# Nemecis

| view | missing objects |

state: visib

In Registry:**ripe** the following objects are referenced but can not be found (in any Registry).

## Missing AS-SETS

- AS--BOSTREAM

- AS--DCS

- AS-10282

- AS-1136

- AS-1140

- AS-1200

- AS-12308

- AS-12350

- AS-1239

- AS-12401

# Nemecis

| view | external warnings | internal warnings | link level policy |

state: visib

## 📁 AS702

⏶ Up one level

| « | [1] 2 3 4 | next 100 items » |

| rpsl ⏶ | last modified | type |
|---|---|---|
| AS702 | 2004/04/30 | AUT_NUM |
| AS702:RS-AT-CUSTOMER | 2004/03/02 | ROUTE_SET |
| AS702:RS-BE | 2003/07/31 | ROUTE_SET |
| AS702:RS-BE-CUSTOMER | 2004/04/07 | ROUTE_SET |
| AS702:RS-CH | 2003/07/31 | ROUTE_SET |
| AS702:RS-CH-CUSTOMER | 2004/03/19 | ROUTE_SET |
| AS702:RS-CUSTOMER | 2004/01/02 | ROUTE_SET |
| AS702:RS-CZ | 2003/07/31 | ROUTE_SET |
| AS702:RS-CZ-CUSTOMER | 2004/03/31 | ROUTE_SET |
| AS702:RS-DE | 2004/04/01 | ROUTE_SET |
| AS702:RS-DE-CUSTOMER | 2004/04/16 | ROUTE_SET |
| AS702:RS-DK | 2003/07/31 | ROUTE_SET |
| AS702:RS-DK-CUSTOMER | 2004/01/02 | ROUTE_SET |
| AS702:RS-ES | 2003/07/31 | ROUTE_SET |
| AS702:RS-ES-CUSTOMER | 2004/02/27 | ROUTE_SET |

```
aut-num:        AS702
as-name:        AS702
descr:          MCI EMEA
descr:          UUNET - Commercial IP service provider in Europe
import:         from AS72 194.98.169.195 at 194.98.169.196 accept AS72
import:         from AS109 213.53.49.50 at 213.53.49.49 accept AS109
import:         from AS137 194.242.224.15 at 194.242.224.18 accept AS-GARR
import:         from AS286 134.222.249.153 at 134.222.249.154 accept AS-KQ AS-QWEST
import:         from AS286 80.81.192.22 at 80.81.192.1 accept AS-KQ
import:         from AS286 148.188.57.158 at 148.188.57.157 accept AS-KPNQWESTEU
import:         from AS334 195.66.224.25 at 195.66.224.17 accept AS-VBCNETGB
import:         from AS553 192.67.199.71 at 192.67.199.7 accept AS-BELWUE
import:         from AS553 80.81.192.175 at 80.81.192.1 accept AS-BELWUE
import:         from AS680 149.227.129.26 at 149.227.129.25 accept AS-DFNTOWINISP
import:         from AS680 149.227.129.22 at 149.227.129.21 accept AS-DFNTOWINISP
import:         from AS701 137.39.30.141 at 137.39.30.142 accept ANY
import:         from AS701 137.39.30.109 at 137.39.30.110 accept ANY
import:         from AS701 137.39.30.121 at 137.39.30.122 accept ANY
import:         from AS701 137.39.30.137 at 137.39.30.138 accept ANY
import:         from AS701 137.39.30.145 at 137.39.30.146 accept ANY
import:         from AS701 137.39.30.133 at 137.39.30.134 accept ANY
import:         from AS701 137.39.7.46 at 146.188.0.114 accept ANY
import:         from AS701 137.39.5.167 at 146.188.0.134 accept ANY
import:         from AS701 137.39.5.168 at 146.188.0.135 accept ANY
import:         from AS701 137.39.30.105 at 137.39.30.106 accept ANY
import:         from AS701 137.39.30.117 at 137.39.30.118 accept ANY
import:         from AS703 146.188.8.33 at 146.188.8.34 accept ANY
import:         from AS705 146.188.9.242 at 146.188.9.241 accept AS705
import:         from AS705 146.188.9.246 at 146.188.9.245 accept AS705
import:         from AS705 146.188.9.234 at 146.188.9.233 accept AS705
import:         from AS705 146.188.9.238 at 146.188.9.237 accept AS705
import:         from AS705 146.188.2.197 at 146.188.2.198 accept AS705
import:         from AS705 146.188.2.201 at 146.188.2.202 accept AS705
import:         from AS705 146.188.12.122 at 146.188.12.121 accept AS705
```

# Nemecis

| view | external warnings | internal warnings | link level policy |

state: vis

## 📁 AS702

🔺 Up one level

**AS702 registers links with the following peers, but they don't register the link.**

- 72

- 137

- 334

- 701

- 703

- 705

- 789

- 790

- 1239

# Nemecis

| view | external warnings | internal warnings | link level policy |

state: visib

## 📁 AS702

▲ Up one level

**AS702 exports the following objects, that we can not find from where it imports them.**

- 12391

- 12402

- 13038

- 13153

- 15414

- 15536

- 15617

- 15764

- 15853

# Nemecis

| view | external warnings | internal warnings | link level policy |
|------|-------------------|-------------------|-------------------|

state: visib

## 📁 AS702

▲ Up one level

The following table contains the import – export correlations for AS702. We find the link–level policy of an A using this table.

[1] 2 3 4 ... 10                                                                    next 100 items »

| name ▲ | import link | own | parent | level |
|--------|-------------|-----|--------|-------|
| AS702:RS-AT | -2 | 0 | -1 | 0 |
| AS702:RS-AT-CUSTOMER | 13237 | 1 | -1 | 0 |
| AS702:RS-BE | -1 | 1 | -1 | 0 |
| AS702:RS-BE-CUSTOMER | -1 | 1 | -1 | 0 |
| AS702:RS-CH | -2 | 1 | -1 | 0 |
| AS702:RS-CH-CUSTOMER | -1 | 1 | -1 | 0 |
| AS702:RS-CUSTOMER | -1 | 1 | -1 | 0 |
| AS702:RS-CZ | -2 | 1 | -1 | 0 |
| AS702:RS-CZ-CUSTOMER | -1 | 1 | -1 | 0 |
| AS702:RS-DE | -1 | 1 | -1 | 0 |
| AS702:RS-DE-CUSTOMER | -1 | 1 | -1 | 0 |
| AS702:RS-DK | -2 | 1 | -1 | 0 |
| AS702:RS-DK-CUSTOMER | -1 | 1 | -1 | 0 |
| AS702:RS-ES | -2 | 1 | -1 | 0 |
| AS702:RS-ES-CUSTOMER | -1 | 1 | -1 | 0 |
| AS702:RS-EURO | -1 | 1 | -1 | 0 |
| AS702:RS-FI | -2 | 1 | -1 | 0 |

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# Questions:

- Is anyone using the aut-num record?

- What could be an actual use?

- Should 'we' revisit the requirements for cooperation?

- What information should the registries contain?

- Who should operate these registries?

- Do 'we' need a more human-centered IRR?

# Conclusions

- The first effort to quantify the consistency of IRR

- RIPE is the best registry (over 2100 ASes)

- Useful information exists in the Registries.

- We are actively seeking feedback from the community.

- Is our tool helpful to you?

- How can we improve it?

- To use our demo please visit:

## http://ira.cs.ucr.edu:8080/Nemecis