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# Schengen Routing: A Compliance Analysis

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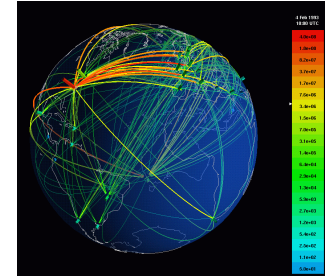
Introduction, Background  
Problem, Approach  
Evaluation, Findings  
Tool, Outlook



# Introduction

<http://lovetomorrowtoday.com/2009/08/20/internet-routing-algorithm-that-could-cut-energy-use-by-40/>

- **Technical status (for sure):**
  - Internet is based on independently operated, but interconnected Autonomous Systems (AS)
  - “Routing is the process of selecting best paths in a network.”
    - Hierarchy of Border Gateway Protocol (BGP) and AS-internal routing protocols combines independent ASes



- **Non-technical status (most likely):**

<http://endthelie.com/books-and-reading-material/how-the-nsa-warrantless-wiretap-system-works/>

- Large amounts of Internet traffic are being **wiretapped** by intelligence agencies
- Tapping reasons manifold
  - Anti-terrorism investigations, (industrial) espionage, ...
- Recent “proof” of this due to interviews with E. Snowden



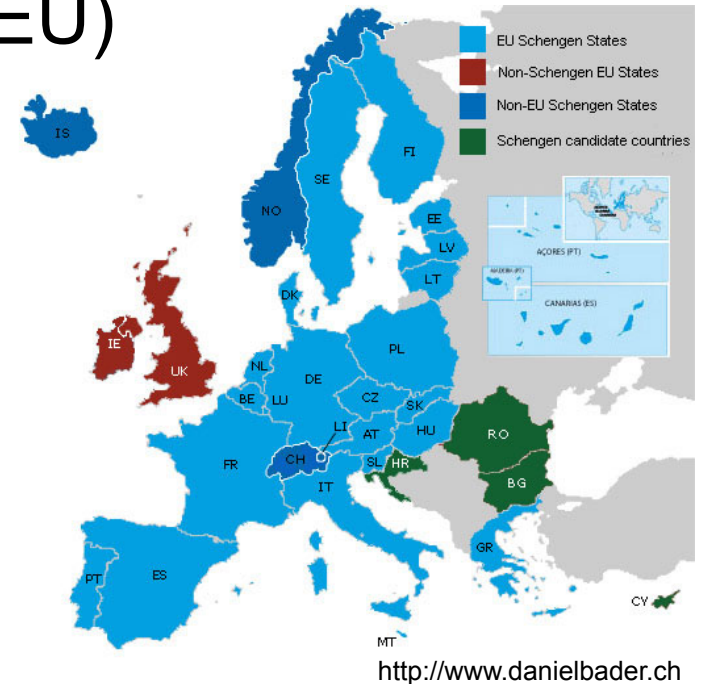
# Countermeasures

- ❑ Multiple organizational, legal, technical possibilities
  - Decouple (threatened) ASes from the global Internet
  - Set-up of wiretapping laws of global scale
    - Besides country- and region-specific acts
    - Monitor and enforce potential misuse (as far as technically possible)
  - Provide and apply encryption technologies
    - Within ASes, between ASes, end-to-end (user)
    - Virtual Private Networks, Transport Layer Security, E2E Security ...
    - ... and limit and control Internet routing based on geography!
      - “Schengen Routing” was proposed as a potential countermeasure
- ❑ **Schengen Routing** refers to the practice of routing Internet traffic within the Schengen area



# Schengen Agreement

- “Schengen Agreement” created Europe’s borderless Schengen area (different than the EU)
  - Treaty signed June 14, 1985 in Luxembourgish town of Schengen by Belgium, France, Luxembourg, The Netherlands, and West Germany
- 1990 agreement supplemented by Schengen Convention
  - Abolition of internal border controls
  - Common visa policy
- Implemented from 1995 onwards
  - Today 26 European countries participate



# Schengen Routing (1)

- ❑ Schengen Routing shall border European and national Internet traffic to the EC's jurisdiction, such that
  - third parties will not have access to that traffic and
  - in case of illegal access, EC laws and regulations will apply.
- ❑ Different voices (from mid to end 2014)
  - Security expert S. Gaycken (TU Berlin, Germany): “Schengen Routing will impede mass surveillance of citizens.”  
<http://www.golem.de/news/nsa-totruersten-experten-fordern-verschluesselung-und-schengen-routing-1406-107493.html>
  - USA opposes the “Schengen cloud” Euro-centric routing plan. All routes should transit America, apparently.  
[http://www.theregister.co.uk/2014/04/07/keeping\\_data\\_away\\_from\\_the\\_us\\_not\\_on\\_ustr/](http://www.theregister.co.uk/2014/04/07/keeping_data_away_from_the_us_not_on_ustr/)
  - “Territorial networks doubtful”, C. Singer (Bundesministerium für Verkehr, Innovation und Technologie BMVIT, Germany).  
“But, Schengen Routing may be valid in some cases.”  
<http://futurezone.at/netzpolitik/euro-cloud-und-schengen-routing-totaler-unsinn/85.135.102>

# Schengen Routing (2)

- “Deutsche Telekom AG (DTAG) has called for statutory requirements that all data generated within the EU not be unnecessarily routed outside of the EU.”

[http://www.theregister.co.uk/2014/04/07/keeping\\_data\\_away\\_from\\_the\\_us\\_not\\_on\\_ustr/](http://www.theregister.co.uk/2014/04/07/keeping_data_away_from_the_us_not_on_ustr/)

- DTAG’s network – in contrast to many others – is managed centrally; the heart is the International Network Management Center (INMC) in Frankfurt.




<http://www.vdi-nachrichten.com/Technik-Wirtschaft/Ein-Schengen-Routing-faktisch-da>, Foto: ap

# Problem Statement and Approach

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- ❑ To which extent does **current Internet traffic in Europe already comply** with the Schengen Routing idea?
- ❑ “Routing” called for **“traceroute”-based measurements**, as they allow for a tracking of paths packets travel
- ❑ The measurement approach consisted out of four steps:
  1. Test-bed/measurement infrastructure selection
  2. Selection of ASes within Schengen
  3. Measurement execution
  4. Results processing

# 1. Test-bed Selection

- Multiple test-beds as **measurement infrastructures**:
    - **Planet-Lab**: World-wide research machines/network: 690+ sites
    - **EMANICSLab**: European research machines/network: 11 sites
    - **BISmark**: World-wide measurement and applications infrastructure in broadband access networks: 80+ sites
    - **RIPE Atlas**: World-wide, volunteer low-cost probes (8300+)
  - Infrastructure **selection criteria**
    - “traceroute-enabled” for retrieving IP addresses and paths
    - Large coverage of European ASes
    - Easy access from research perspective
    - Non-intrusive behavior of measurements required
    - Valuable outcomes and data in analyzable form  **RIPE NCC** RIPE NETWORK COORDINATION CENTRE
- **RIPE Atlas** selected due to **extensive AS coverage**



## 2. AS Selection

### □ ASes selected based on Maxmind's GeoLite database:

– Maps IP address ranges to ASes and countries

- First file content: <From IP> <To IP> <AS Number>

– Example: 5 10 AS1

- Second file content: <From IP> <To IP> <Country Code>

– Example 5 10 CH: Ranges 5 to 10 belong to AS1 within Switzerland (CH)

– Calculation of IP addresses per AS and country

- AS and country ranges did not always match, since IP Ranges can be disjoint in the two files → sub-ranges

- Example:  $10 - 5 + 1 = 6$ : defining 6 IP addresses to be in CH

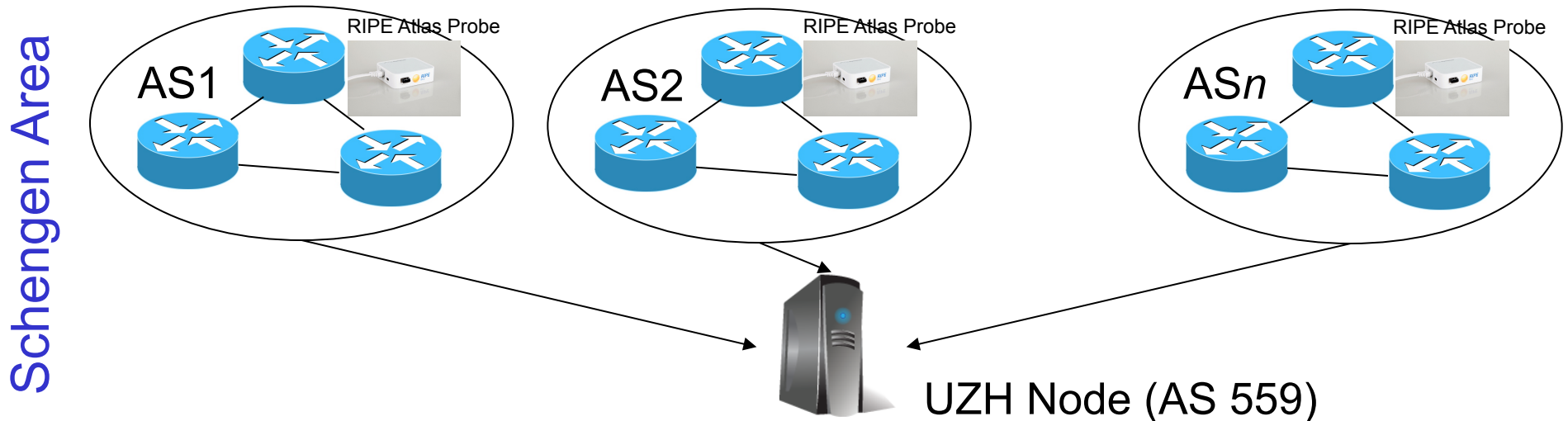
→ AS was selected, if at least one IP address in Schengen

9967 ASes were found to be located in Schengen



# 3. Measurement Execution

- ❑ traceroute measurements were run from probes of ASes, located in Schengen and selected, toward a UZH node



- ❑ Active measurements used following protocols:
  - TCP, UDP, and ICMP (3 each)
  - Requests were submitted to all 9967 ASes found





*Note: RIPE credits available only for limited number of measurements*

# 4. Results Processing

- From 9967 ASes selected (in Schengen) and supplied with a measurement execution only 1306 (minus no probes) responded, as 8661 ASes are not covered by a RIPE probe.
  - Measurements with failing results (error messages) were excluded.
  - ASes may show IP addresses in several countries. As RIPE chooses a probe at its own discretion, outside Schengen IP addresses were excluded, too.
- Only a smaller fraction of results useable for analysis

| <i>Original</i> | <i>Not Covered</i> | <i>No Probes</i> |     |      |
|-----------------|--------------------|------------------|-----|------|
|                 |                    | TCP              | UDP | ICMP |
| 9967            | 8661               | 44               | 47  | 50   |

# Evaluation

- Results **classified** wrt **Schengen routing compliance**, *i.e.*, all intermediate hops in a traceroute measurement can be determined as being “inside” or “outside” Schengen:
  - Geographic location of IP address determined by Maxmind
  - All IP addresses of a collected route inside Schengen
    - Compliant 
  - At least one IP address outside Schengen
    - Non-compliant 
  - If traceroute result contains unknown addresses
    - If all other IP addresses inside Schengen:
      - Unknown 
    - If at least one IP address outside Schengen:
      - Non-compliant 

# Findings (1)

## □ Routes: compliant

- Overall: TCP: 34.5%, UDP: 37.4%, ICMP: 39.7%
- Least compliant: Malta: TCP: 0%, UDP: 0%, ICMP: 0%
- Most compliant: Liechtenstein: TCP: 80%, UDP: 75%, ICMP: 80%

## □ Routes: non-compliant

- Overall: TCP: 33.8%, UDP: 38.7%, ICMP: 42.3%
- Least non-compliant: Liechtenstein: TCP: 0%, ICMP: 20%,  
Switzerland: UDP: 19.4%
- Most non-compliant: Estonia: TCP: 81.8%, UDP: 81.8%, ICMP: 84.8%

## □ Routes: unknown

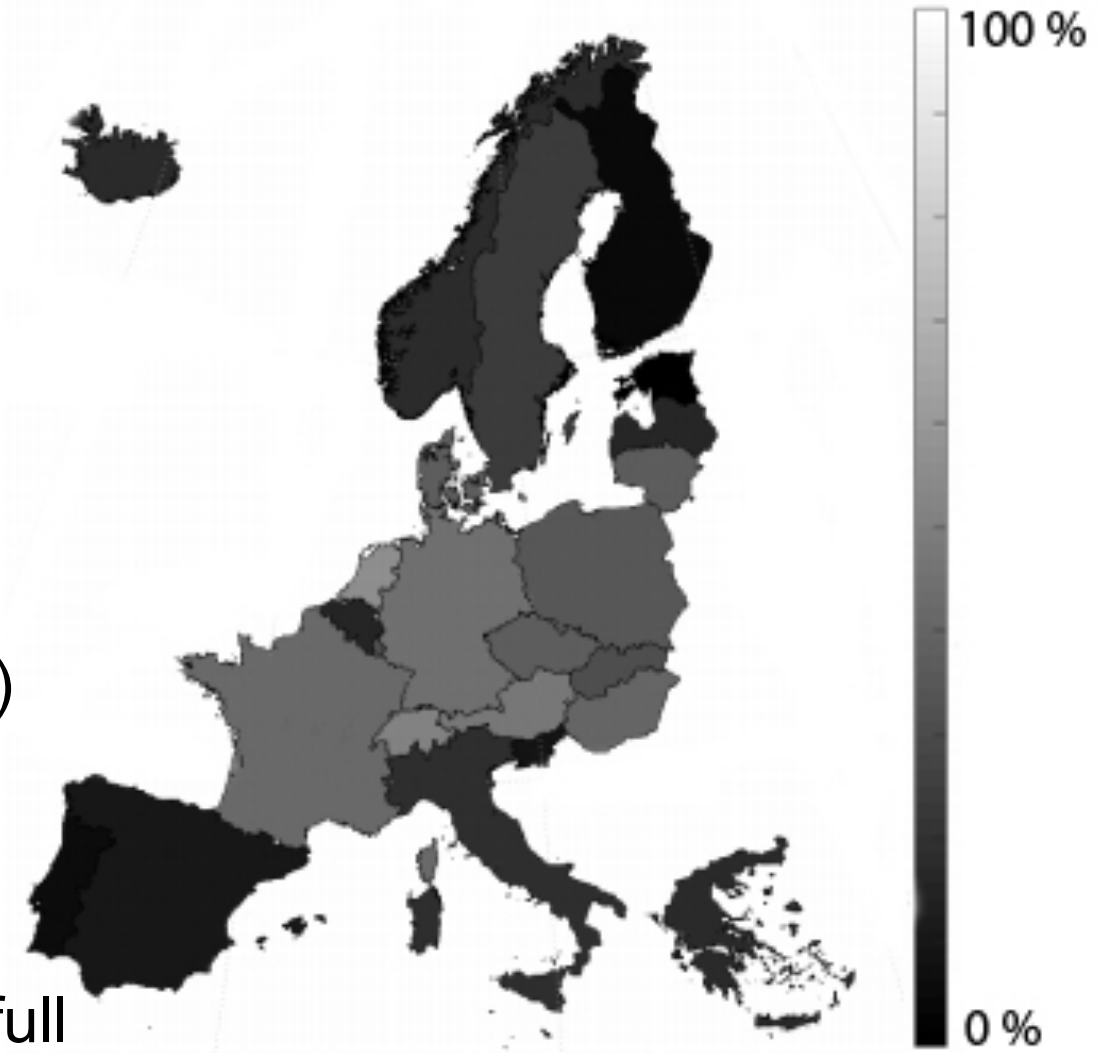
- TCP (least/most): Estonia: 18.2% Italy: 50%
- UDP: (least/most): Liechtenstein: 0% Italy: 42.4%
- ICMP: (least/most): Liechtenstein: 0% Italy: 41.1%

# Findings (2)

| R     | ISO | TCP  |      |      |       |      |        | UDP  |       |      |      |      |       | ICMP |        |     |       |      |      |      |       |      |        |     |       |
|-------|-----|------|------|------|-------|------|--------|------|-------|------|------|------|-------|------|--------|-----|-------|------|------|------|-------|------|--------|-----|-------|
|       |     | ASs  | T    | C    | C (%) | NC   | NC (%) | U    | U (%) | ASs  | T    | C    | C (%) | NC   | NC (%) | U   | U (%) | ASs  | T    | C    | C (%) | NC   | NC (%) | U   | U (%) |
| 1     | LI  | 5    | 15   | 12   | 80.0% | 0    | 0.0%   | 3    | 20.0% | 4    | 12   | 9    | 75.0% | 3    | 25.0%  | 0   | 0.0%  | 5    | 15   | 12   | 80.0% | 3    | 20.0%  | 0   | 0.0%  |
| 2     | NL  | 88   | 264  | 148  | 56.1% | 51   | 19.3%  | 65   | 24.6% | 88   | 264  | 165  | 62.5% | 65   | 24.6%  | 34  | 12.9% | 88   | 264  | 161  | 61.0% | 68   | 25.8%  | 35  | 13.3% |
| 3     | CH  | 66   | 198  | 102  | 51.5% | 30   | 15.2%  | 66   | 33.3% | 67   | 201  | 126  | 62.7% | 39   | 19.4%  | 36  | 17.9% | 66   | 198  | 132  | 66.7% | 44   | 22.2%  | 22  | 11.1% |
| 4     | AT  | 56   | 168  | 79   | 47.0% | 42   | 25.0%  | 47   | 28.0% | 56   | 168  | 77   | 45.8% | 59   | 35.1%  | 32  | 19.0% | 56   | 168  | 89   | 53.0% | 64   | 38.1%  | 15  | 8.9%  |
| 5     | DE  | 192  | 576  | 253  | 43.9% | 187  | 32.5%  | 136  | 23.6% | 189  | 567  | 266  | 46.9% | 198  | 34.9%  | 103 | 18.2% | 188  | 564  | 280  | 49.6% | 210  | 37.2%  | 74  | 13.1% |
| 6     | FR  | 115  | 345  | 143  | 41.4% | 91   | 26.4%  | 111  | 32.2% | 117  | 351  | 155  | 44.2% | 94   | 26.8%  | 102 | 29.1% | 114  | 342  | 170  | 49.7% | 111  | 32.5%  | 61  | 17.8% |
| 7     | HU  | 20   | 60   | 24   | 40.0% | 23   | 38.3%  | 13   | 21.7% | 21   | 63   | 28   | 44.4% | 26   | 41.3%  | 9   | 14.3% | 20   | 60   | 27   | 45.0% | 27   | 45.0%  | 6   | 10.0% |
| 8     | CZ  | 81   | 243  | 90   | 37.0% | 76   | 31.3%  | 77   | 31.7% | 80   | 240  | 91   | 37.9% | 83   | 34.6%  | 66  | 27.5% | 81   | 243  | 102  | 42.0% | 94   | 38.7%  | 47  | 19.3% |
| 9     | DK  | 38   | 114  | 42   | 36.8% | 30   | 26.3%  | 42   | 36.8% | 38   | 114  | 53   | 46.5% | 33   | 28.9%  | 28  | 24.6% | 38   | 114  | 53   | 46.5% | 36   | 31.6%  | 25  | 21.9% |
| 10    | LT  | 11   | 33   | 12   | 36.4% | 12   | 36.4%  | 9    | 27.3% | 11   | 33   | 13   | 39.4% | 11   | 33.3%  | 9   | 27.3% | 11   | 33   | 13   | 39.4% | 12   | 36.4%  | 8   | 24.2% |
| 11    | PL  | 78   | 234  | 81   | 34.6% | 96   | 41.0%  | 57   | 24.4% | 78   | 234  | 73   | 31.2% | 108  | 46.2%  | 53  | 22.6% | 78   | 234  | 78   | 33.3% | 117  | 50.0%  | 39  | 16.7% |
| 12    | LU  | 19   | 57   | 18   | 31.6% | 27   | 47.4%  | 12   | 21.1% | 19   | 57   | 15   | 26.3% | 30   | 52.6%  | 12  | 21.1% | 19   | 57   | 17   | 29.8% | 33   | 57.9%  | 7   | 12.3% |
| 13    | SK  | 13   | 39   | 12   | 30.8% | 13   | 33.3%  | 14   | 35.9% | 13   | 39   | 12   | 30.8% | 16   | 41.0%  | 11  | 28.2% | 13   | 39   | 12   | 30.8% | 19   | 48.7%  | 8   | 20.5% |
| 14    | SE  | 58   | 174  | 41   | 23.6% | 53   | 30.5%  | 80   | 46.0% | 58   | 174  | 72   | 41.4% | 63   | 36.2%  | 39  | 22.4% | 59   | 177  | 69   | 39.0% | 69   | 39.0%  | 39  | 22.0% |
| 15    | IT  | 70   | 210  | 39   | 18.6% | 66   | 31.4%  | 105  | 50.0% | 70   | 210  | 43   | 20.5% | 78   | 37.1%  | 89  | 42.4% | 69   | 207  | 45   | 21.7% | 77   | 37.2%  | 85  | 41.1% |
| 16    | NO  | 41   | 123  | 21   | 17.1% | 51   | 41.5%  | 51   | 41.5% | 41   | 123  | 17   | 13.8% | 65   | 52.8%  | 41  | 33.3% | 40   | 120  | 21   | 17.5% | 62   | 51.7%  | 37  | 30.8% |
| 17    | GR  | 24   | 72   | 12   | 16.7% | 44   | 61.1%  | 16   | 22.2% | 24   | 72   | 12   | 16.7% | 40   | 55.6%  | 20  | 27.8% | 24   | 72   | 12   | 16.7% | 46   | 63.9%  | 14  | 19.4% |
|       | IS  | 6    | 18   | 3    | 16.7% | 7    | 38.9%  | 8    | 44.4% | 6    | 18   | 3    | 16.7% | 9    | 50.0%  | 6   | 33.3% | 6    | 18   | 3    | 16.7% | 9    | 50.0%  | 6   | 33.3% |
| 19    | LV  | 13   | 39   | 6    | 15.4% | 24   | 61.5%  | 9    | 23.1% | 13   | 39   | 3    | 7.7%  | 29   | 74.4%  | 7   | 17.9% | 13   | 39   | 3    | 7.7%  | 33   | 84.6%  | 3   | 7.7%  |
| 20    | BE  | 27   | 81   | 12   | 14.8% | 40   | 49.4%  | 29   | 35.8% | 27   | 81   | 9    | 11.1% | 52   | 64.2%  | 20  | 24.7% | 26   | 78   | 14   | 17.9% | 58   | 74.4%  | 6   | 7.7%  |
| 21    | ES  | 43   | 129  | 12   | 9.3%  | 56   | 43.4%  | 61   | 47.3% | 43   | 129  | 14   | 10.9% | 73   | 56.6%  | 42  | 32.6% | 42   | 126  | 16   | 12.7% | 83   | 65.9%  | 27  | 21.4% |
| 22    | SI  | 16   | 48   | 4    | 8.3%  | 28   | 58.3%  | 16   | 33.3% | 15   | 45   | 6    | 13.3% | 35   | 77.8%  | 4   | 8.9%  | 16   | 48   | 6    | 12.5% | 39   | 81.3%  | 3   | 6.3%  |
| 23    | PT  | 13   | 39   | 2    | 5.1%  | 26   | 66.7%  | 11   | 28.2% | 13   | 39   | 3    | 7.7%  | 28   | 71.8%  | 8   | 20.5% | 13   | 39   | 3    | 7.7%  | 31   | 79.5%  | 5   | 12.8% |
| 24    | FI  | 25   | 75   | 3    | 4.0%  | 42   | 56.0%  | 30   | 40.0% | 26   | 78   | 3    | 3.8%  | 45   | 57.7%  | 30  | 38.5% | 26   | 78   | 3    | 3.8%  | 51   | 65.4%  | 24  | 30.8% |
| 25    | EE  | 11   | 33   | 0    | 0.0%  | 27   | 81.8%  | 6    | 18.2% | 11   | 33   | 0    | 0.0%  | 27   | 81.8%  | 6   | 18.2% | 11   | 33   | 0    | 0.0%  | 28   | 84.8%  | 5   | 15.2% |
|       | MT  | 3    | 9    | 0    | 0.0%  | 6    | 66.7%  | 3    | 33.3% | 3    | 9    | 0    | 0.0%  | 5    | 55.6%  | 4   | 44.4% | 3    | 9    | 0    | 0.0%  | 5    | 55.6%  | 4   | 44.4% |
| Total |     | 1132 | 3396 | 1171 | 34.5% | 1148 | 33.8%  | 1077 | 31.7% | 1131 | 3393 | 1268 | 37.4% | 1314 | 38.7%  | 811 | 23.9% | 1125 | 3375 | 1341 | 39.7% | 1429 | 42.3%  | 605 | 17.9% |

# Findings (3)

- ❑ Overall **compliance level** in percent per country
  - Dark grey: lower compliance (🏠)
  - Light grey: higher compliance (“✓”)
- ❑ Significant **variances** among countries
  - No country complies in full



# Related Work Comparison

- Pohlman et al. ran a passive approach (BGP tables)
  - Maxmind data base used, too
  - Different “compliance”: Majority of assigned IP address range is located in Schengen”
- Active measurements values here exceed results

| Country Code | Country       | Pohlmann et al. | chkroute |
|--------------|---------------|-----------------|----------|
| BE           | Belgium       | 35.38%          | 49.4%    |
| LI           | Liechtenstein | 29.41%          | 0.0%     |
| CH           | Switzerland   | 23.48%          | 15.2%    |
| ES           | Spain         | 21.27%          | 43.4%    |
| LU           | Luxembourg    | 21.15%          | 47.4%    |
| FR           | France        | 19.13%          | 26.4%    |
| MT           | Malta         | 17.86%          | 66.7%    |
| FI           | Finland       | 16.58%          | 56.0%    |
| CZ           | CzechRepublic | 16.31%          | 31.3%    |
| SE           | Sweden        | 14.92%          | 30.5%    |
| NL           | Netherlands   | 13.07%          | 19.3%    |
| DE           | Germany       | 12.26%          | 32.5%    |
| NO           | Norway        | 10.31%          | 41.5%    |
| GR           | Greece        | 8.67%           | 61.1%    |
| EE           | Estonia       | 6.78%           | 81.8%    |
| SK           | Slovakia      | 6.25%           | 33.3%    |
| LT           | Lithuania     | 5.50%           | 36.4%    |
| IT           | Italy         | 3.70%           | 31.4%    |
| AT           | Austria       | 3.23%           | 25.0%    |
| DK           | Denmark       | 1.75%           | 26.3%    |
| PL           | Poland        | 1.43%           | 41.0%    |
| PT           | Portugal      | 1.39%           | 66.7%    |
| LV           | Latvia        | 1.34%           | 61.5%    |
| SI           | Slovenia      | 1.15%           | 58.3%    |
| HU           | Hungary       | 0.49%           | 38.3%    |
| IS           | Iceland       | 0.00%           | 38.9%    |

Non-compliant routes only



# View Expressed a Year Ago (April 4, 2014)

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- “Data with European-internal sender and receiver address will be exchanged within local networks across a close-by IXP. 98.2% of this traffic remain already in Europe”, Klaus Landefeld, representative of the CEO of the Association of the German Internet Economy Eco. “Schengen Routing will improve this situation by about 2% only.”

<http://www.vdi-nachrichten.com/Technik-Wirtschaft/Ein-Schengen-Routing-faktisch-da>

- Contradiction with those results just presented?

# The Tool “chkroute”

- Besides numerical results in general, users may be interested to check a **compliance of a certain route**

- The **tool** “chkroute” checks that <http://www.csg.uzh.ch/publications/software/chkroute.html>
- Developed as a **shell utility**
  - Available for Linux, Mac OS

- **Tool output**

- Traffic **remains** within Schengen area until hop 7
- Traffic **leaves** Schengen area for hops 8 to 11
- Traffic **returns** to Schengen area at hop 12

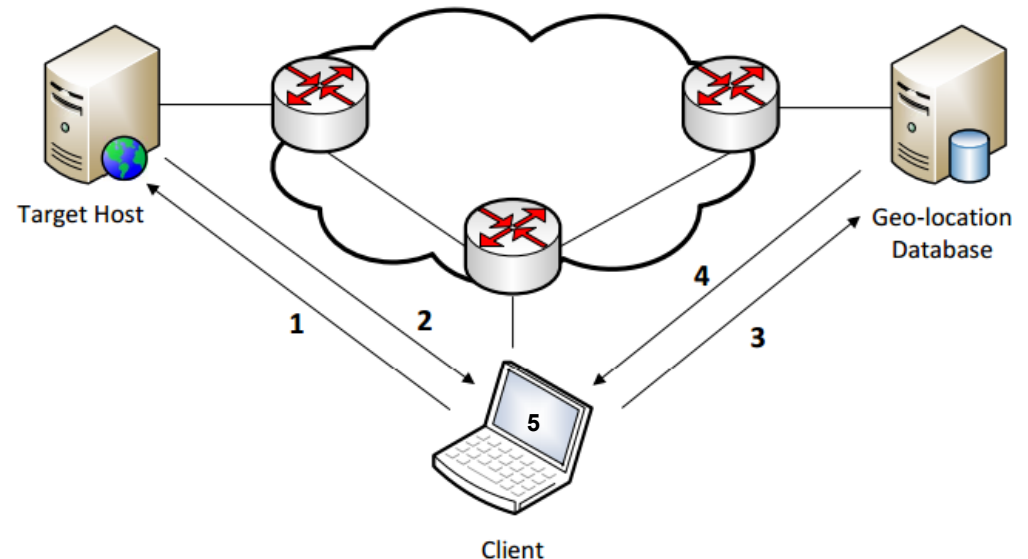
```
daniel@daniel-csg:~/chkroute/bin$ ./chkroute.sh www.unibw.de
```

| Hop | Host          | Country | Compliant | AS No   |
|-----|---------------|---------|-----------|---------|
| 1   | 130.60.156.1  | CH      | Y         | 559     |
| 2   | 10.1.2.157    | Local   | Y         | Unknown |
| 3   | 10.1.0.78     | Local   | Y         | Unknown |
| 4   | 10.1.0.58     | Local   | Y         | Unknown |
| 5   | 192.41.136.65 | CH      | Y         | 559     |
| 6   | 192.41.136.1  | CH      | Y         | 559     |
| 7   | 130.59.36.1   | CH      | Y         | 559     |
| 8   | 62.40.124.81  | GB      | N         | 20965   |
| 9   | 62.40.98.76   | GB      | N         | 20965   |
| 10  | 62.40.98.81   | GB      | N         | 20965   |
| 11  | 62.40.112.146 | GB      | N         | 20965   |
| 12  | 188.1.144.186 | DE      | Y         | 680     |
| 13  | *             | Unknown | Unknown   | Unknown |
| 14  | 188.1.231.254 | DE      | Y         | 680     |
| 15  | 137.193.9.169 | DE      | Y         | 680     |
| 16  | 137.193.6.24  | DE      | Y         | 680     |

# chkroute Architecture

□ Route compliance is established as follows:

1. Client runs “traceroute” against a target host (DNS name)
2. Client collects responses from hops along the path
3. Client submits hops to the geo-location data base
4. Geo-location data base analyzes hops and sends country and compliance information back to the client
5. Client prints the result



# Discussion and Outlook

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- Although
  - inaccuracies of Maxmind data base (though large) and
  - non-representative locations for RIPE Atlas probes exist,  
protocol-specific results collected!
- For those active measurements it was found that
  - S. Routing compliance is not achieved in any S. country
  - S. Routing compliance levels vary widely among S. countries
- Future steps
  - Analyze reverse path of routes and changes over time
  - Analyze results for target nodes located in other S. countries
    - Analyze exit and entry points from/into Schengen area
  - Analyze ASes rather than countries

# Acknowledgements

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<http://www.csg.uzh.ch>

*Especially Thomas Bocek*



<http://www.fp7-flamingo.eu>



<http://www.smartenit.eu>