Worldwide Secure and Efficient Communication with SCION

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Nicola Rustignoli
Network Security Group, ETH Zürich

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Overall plan:

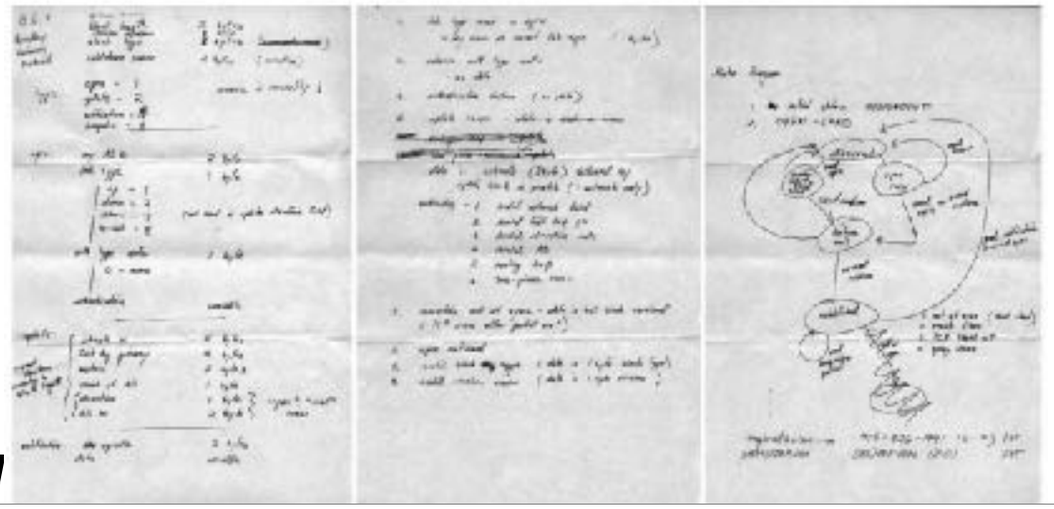
- Introduction to SCION
  - BGP Story, internet on Fire
  - What we did about it: restart from scratch
  - Properties: efficiency, path control, geofencing
  - Not a research project, a global internet today

- Path aware architecture
- Green routing
- ICRC

- This is real and running
- Do you want to be part of next gen internet?

Incredible Story

- BGP was designed in 1989 by Kirk Lougheed and Yakov Rekhter on three paper napkins over lunch, and today the Internet relies on it!



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Let’s start our discussion with an incredible story …

1969: UCLA sends the first internet message to the Stanford Research Institute. The message was “login”, which only “lo” was received. This is the first successful internet message.

1984: Exterior gateway protocol was developed. It was conceptually discussed in 1982, but the formal announcement did not come until RFC 904. EGP was a tree-like distance-vector internet routing protocol.

1988: Routing Information Protocol (RIP) (RFC 1058), is developed. This is the oldest distance-vector routing protocol in its modern context. This begins to lay the groundwork for BGP.

January 1989, in Austin, Texas at the Internet Engineering Task Force (IETF), BGP is created. Drawn on three sheets of paper, Yakov Rekhter of IBM and Kirk Lougheed of Cisco, design BGP. The original three sheets of paper are hanging in Cisco’s modern day offices.
In June of this year, the internet memo, RFC 1105, is released with BGP version 1. This changes internet routing protocols from being tree-like topologies into the modern mesh topologies we have today.

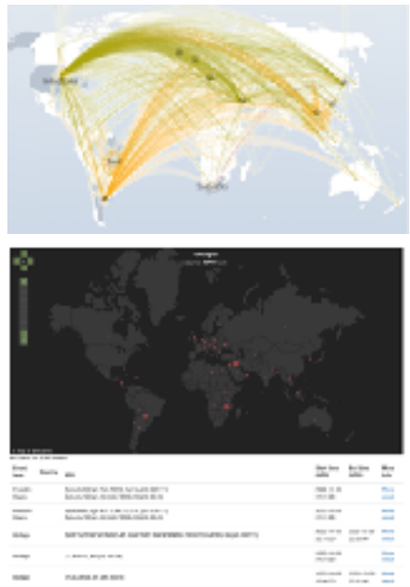
The BGP protocol was designed in 1989 by Lougheed and Rekhter, and specified in the document RFC 1105. The initial design fit on three napkins, so it’s sometimes referred to as the three-napkin-protocol. Since its inception, BGP has become one of the most important Internet protocols, as it determines the networking paths from a source toward a destination.

1995: BGP version 4 is released (RFC 1771)

https://medium.com/@datapath_io/the-history-of-border-gateway-protocol-a212b7ee6208

The Internet is on Fire!

- Lack of sovereignty
- Frequent outages
  - https://downdetector.com
- Constant DDoS attacks
  - https://www.digitalattackmap.com
- Frequent routing attacks
  - https://bgpstream.com
- Lack of communication guarantees
- Expensive maintenance



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The Internet is on fire not only because of its rapid expansion, but also because of several shortcomings that have been burning issues for decades.

New Internet Architecture: Goals and Desires

- Internet to support applications?
  - Cloud computing
  - Mobility
  - Video streaming
  - IoT
- Internet to provide properties?
  - Security
  - Low latency
  - Privacy, anonymity
  - High performance & low energy impact
  - High availability, rapid failover

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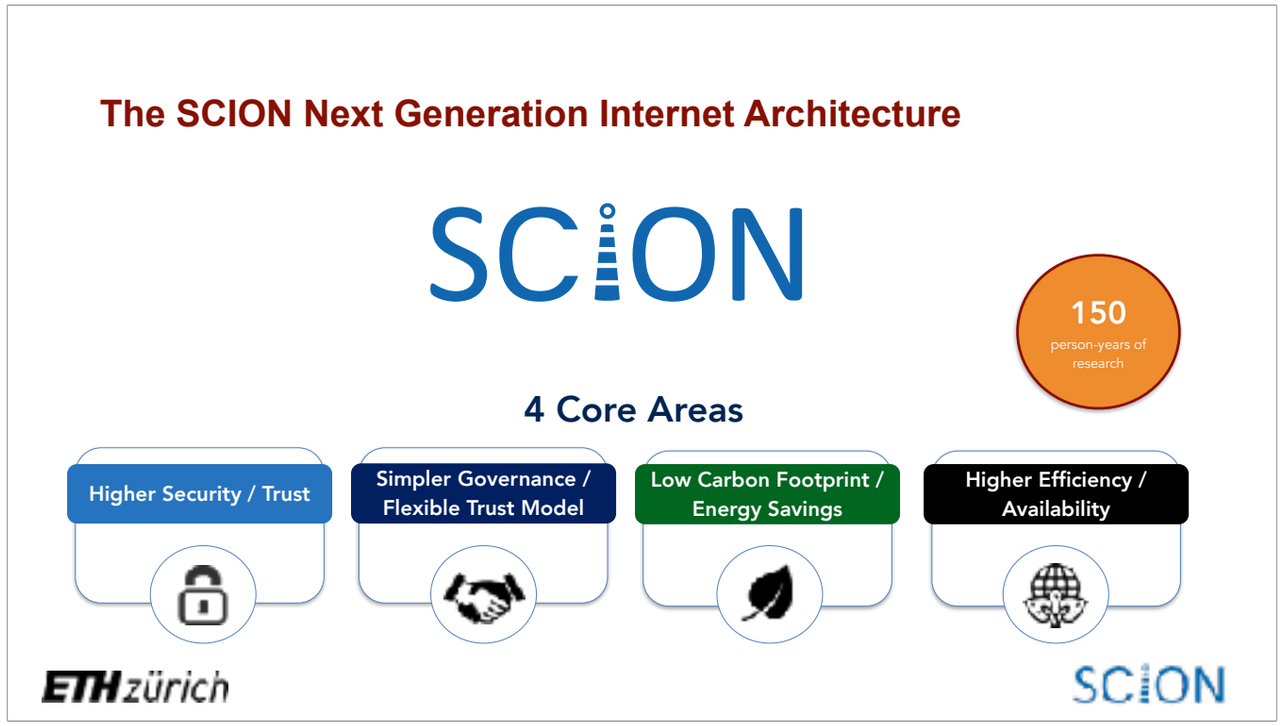
What do we want? All of the applications and properties!



- Highly secure and available communication (most network attacks impossible by design)
- Simple & multilateral governance model (Sovereign internet operation and tolerance to malicious behaviour in other countries)
- Green & Efficient
- Higher availability (fit for critical infrastructure)

SCION Overview in One Slide

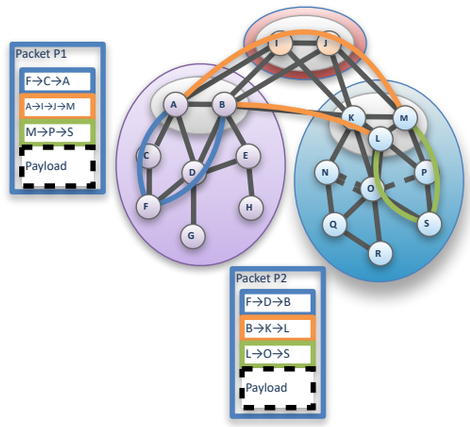
Path-based Network Architecture

Control Plane - Routing

- Constructs and Disseminates Path Segments

Data Plane - Packet forwarding

- Combine Path Segments to Path
- Packets contain Path
- Routers forward packets based on Path
  - Simple routers, stateless operation



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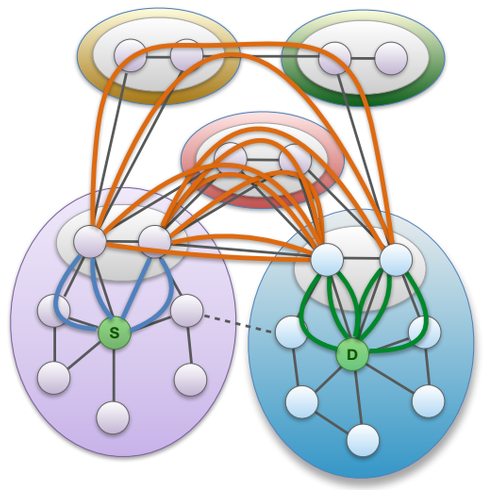
SCION is Massively Multipath

- SCION not only finds many disjoint path segments, but enables a massive number of multipath choices through segment combinations
- In this example, S has 5 path segments to core ASes, D has 6 path segments, and 7 core path segments are provided
- These path segments enable 54 different end-to-end paths!



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2*5 *3 = 30
2*4 *3 = 24

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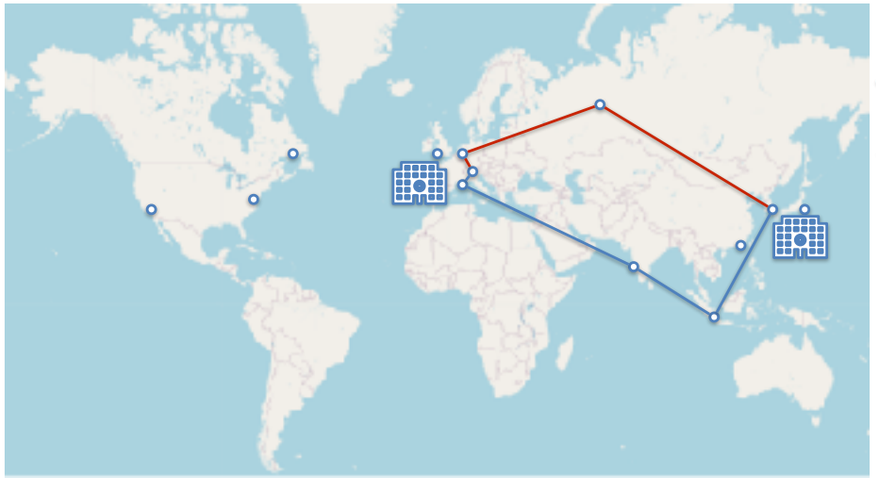
Use Cases

Use case: Enterprise Traffic Management

Performance-based routing & path control



VoIP
(latency optimised)

Generic traffic
(cost optimised)

Optimization criteria

- Latency
- Bandwidth
- Jurisdiction
- CO_2

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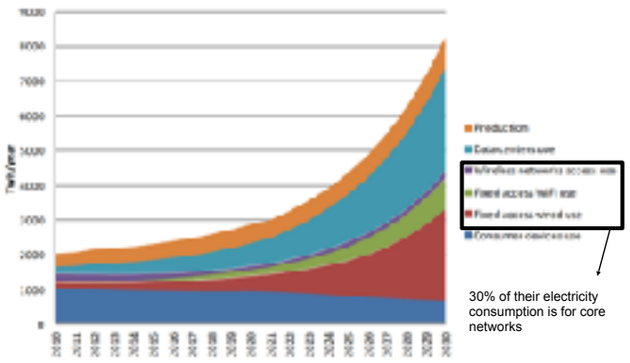
Story is: you are an organisation and want to route your traffic optimally. With SCION you can:
* define fine-grained traffic policies
* Leverage multi path

FYI: this slide is inspired by OrgMan

Use case: Networking Energy Consumption
Performance-based routing & path control

- Communication networks contribute to 15-20% of ICT's electricity consumption
- Its share is expected to increase to 44% by 2030 [Andrea et al. 2015]
  - Traffic increase rate larger than energy efficiency improvement rate
  - Decrease in energy efficiency improvement rate
- Core networks represent 30% of communication networks' electricity consumption



[Andrea et al. 2015]

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Communication Networks → The electricity consumption of Spain, or UK.
Core Networks → 2 times the electricity consumption of Switzerland

We will talk about core networks in the following slides.

The core networks are not SCION core network and means the Internet backbone network. When want to talk about SCION core ASes, we mention that.

- Figure 2. Prediction of the expected contribution of different ICT parts to the whole electricity usage of ICT sector. Core networks included in access networks. Study conducted in 2015.
- Consumer: The decrease in consumer device's energy is because of the decrease in the number of desktops (2010-2020) and laptops (2020-2030) and increase in mobile devices
- Mobile:
  - Decrease in 2G/3G voice, 2G and 3G data. Increase and then decrease in 4G data. Increase in 5G data. 5G is much more energy-efficient than previous generations.
  - Mobile data: 3.84 EB in 2010. +66% per year up to 2017. + 58% per year until 2020. and + 40/50/60 % per year afterwards
  - 5G: Machine-to-Machine and Internet-of-everything applications, utilizing the close synergy between cloud computing, software defined networking (SDN), and network function virtualization
  - 5G efficiency: 0.05/0.06/0.13 TWh/EB
  - 5G Improvement: 0.3/0.22/0.1 per year
- Data Centers:
  - back-end infrastructure for a new generation of thin-client consumer electronics devices
  - provide the backbone for Internet growth
  - Data within and between data centers → grows 23 % per year
  - Data from data center to user = fixed and mobile data
  - Form 1400 EB in 2010 to 156 000 EB data centers traffic in 2030
  - Efficiency: 0.14 TWh/EB, improvement 0.15/0.1/0.05 per year
- Fixed access (including core and wifi access)
  - Increase in data faster than efficiency improvement
  - Consumed 280 TWh in 2013 (32 GW)
  - Traffic can increase from 320 EB in 2010 up to 48 000 EB in year until 2030
  - Efficiency: 0.1-0.2 TWh/EB
  - Improvement: 0.15/0.1/0.05 per year

Routing Over Low-Emission Paths

Forwarding is 30% more efficient that current internet

In our architecture, paths have an associated CO_2 cost, that is cryptographically embedded into packets

ISPs compete and are rewarded for providing green paths. Our simulations show that up to 87% CO2 reduction is possible.

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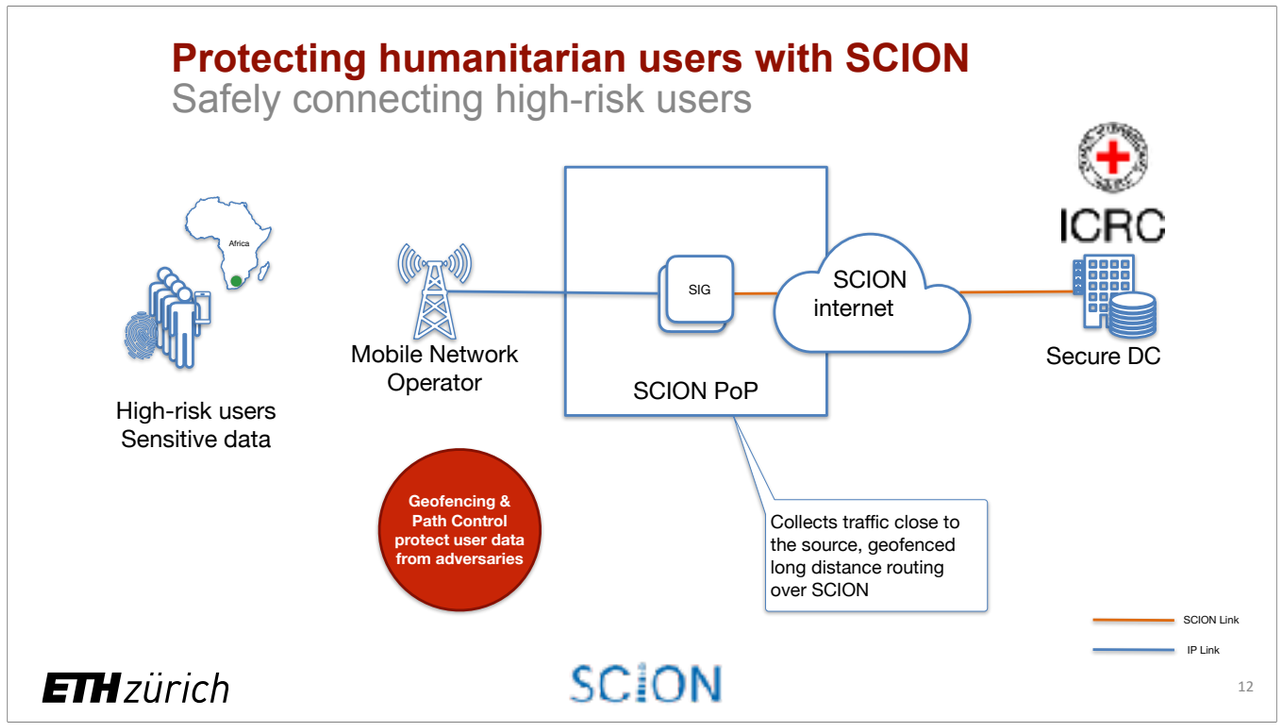
- Energy impact of Internet infrastructure is growing continuously, and 15-20% of it is actually communication infrastructure. This is expected to grow.

  - We built a model for calculating the carbon emission per bit of data on an inter-domain path

- How SCION ASes calculate and disseminate this value to other SCION ASes
- Green import policy and beaconing algorithm
- Evaluation
- Estimate per-bit carbon emission on inter-domain paths
- Evaluate the effect of the green virtuous feedback cycle
- Results
- At least 50% CO2 emission reduction for communication between half of AS pairs
- 210 000 ton of CO2 emission reduction per year
- Negligible effect on latency
- The competition causes 87% reduction in CO2 emission



We are exploring, together with the ICRC, how SCION routing security can improve confidentiality.

information on humanitarian services near you, a digital safe where you can store important documents and a secure messaging service.

volatile and complex environment such as war and natural disasters where privacy and data protection are central to the worries/needs of affected people (because of the consequences linked to the risks – i.e. a data breach can have life and death consequences).

Here we show a case study: (being built as we speak).
We have a high-risk group of users in Africa. They need to safely store sensitive data in a DC in CH, but don't want to be eavesdropped by adversary states.
We collect IP traffic to destined to the secure DC as close as possible to the user.
Thanks to path control and geofencing, we can protect user data from adversary states.

SCION Production Network

- Led by Anapaya Systems
- **BGP-free global communication**
  - Fault independent from BGP protocol
- Deployed with international ISPs
  - First **global public secure** communication network
- Construction of SCION network backbone at select locations to bootstrap adoption
- Current deployment
  - ISPs: Switzerland, Europe and Asia (and growing)
  - IXPs: SwissIX offers SCION peering, more to come
  - Swiss government, financial institutions

Thank you for your attention!

- https://www.scion-architecture.net
  - Book, documents, videos, tutorials
- https://www.scionlab.org
  - SCIONLab testbed
- https://www.anapaya.net
  - ETH-Spin-off offering SCION-based products
- https://github.com/scionproto/scion
  - Open-source code

nicola.rustignoli@inf.ethz.ch
adrian.perrig@inf.ethz.ch

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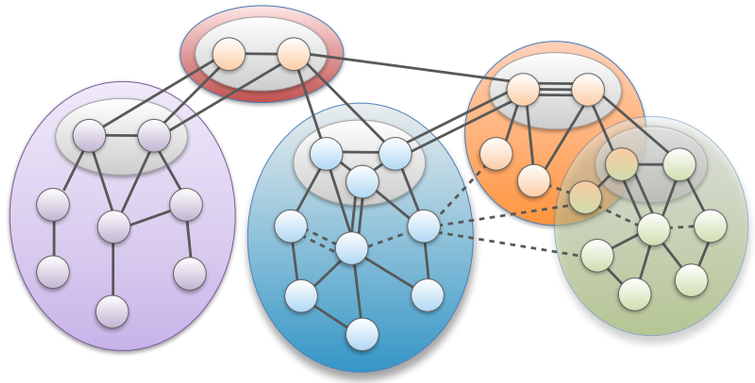
SCION
SCALABILITY, CONTROL, AND ISOLATION
ON NEXT-GENERATION NETWORKS

Appendix

Two-level hierarchy through Isolation Domain (ISD)

- Isolation Domain (ISD): grouping of Autonomous Systems (AS)
- ISD core: ASes that manage the ISD and provide global connectivity
- Core AS: AS that is part of ISD core
- Two-level hierarchical routing: inter-ISD and intra-ISD



SCIONLab

- Global SCION research testbed: https://www.scionlab.org
- Collaboration with David Hausheer's team at University of Magdeburg
- Open to everyone: create and connect your own AS within minutes
- ISPs: Swisscom, SWITCH, KDDI, GEANT, DFN
- Deployed 35+ permanent ASes worldwide, 600+ user ASes
  - Contact us to become an infrastructure AS, we can provide HW
- Kwon et al., "SCIONLab: A Next-Generation Internet Testbed", ICNP 2020

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