SCIONLab: A Next-Generation Internet Testbed

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Network Security Group
Scientists need a proper research environment to carry out experiments to validate or refute a hypothesis.

A network testbed for network researchers.
Internet

More than 4.57 B active users
362 M registered domains
6.5 hours per day
88 TB every second
1239% growth (2000-2020)

Internet was born in 1960
as a research testbed
Network Testbeds at a Glance

Network simulators & emulators
- Mimic the behavior of a live network
- Easy to conduct large-scale experiments
- Provide reproducibility
- Abstraction that cannot model all real-world aspects
- Emulab [OSDI’02], Mininet [HotNet’10]

Real-world network testbeds
- Exposure to real-world effects
- Experiments might not reproducible
- Higher cost for deployment and management
- PlanetLab [OSDI’06], VENI [SIGCOMM’06], GENI [ComNet’14], Peering [CoNEXT’19]
New Research Opportunities

Path-aware networking
- Network provides path information
- End hosts select communication paths
- Source-routing [CCR’77], Pathlet [CCR’09]
  - Path transparency
  - Fine-grained path control
  - Fast failover
  - Geofencing

Multipath communication
- End hosts select path on a per-packet basis
- MPTCP [RFC8401], QUIC [CoNEXT’17]
  - High Bandwidth
  - Efficient link utilization
  - Improved reliability

Secure inter-domain routing
- PKI certifies control plane messages
- SCION [S&P’11], RPKI [RFC6810]
  - Control-plane security
  - Hijacking resilience
  - DDoS resilience
Network researchers need a new playground

SCIONLab: A Next-Generation Internet Testbed

Enabling new research in computer networks, network security, and networked applications

Secure and fine-grained inter-domain routing control along with true multi-path communication
Explained: SCION in One Slide

- Path-based Network Architecture

Control Plane – Routing
- Construct and disseminate path segments
  - Path exploration
  - Path registration
  - Path resolution

Data Plane – Packet forwarding
- Combine path segments for end-to-end path
- Packets contain path
- Routers forward packets based on AS path
  - Simple routers, stateless forwarding

Scalability, Control, and Isolation on Next-generation Networks
SCIONLab Overview

Global Infrastructure

User Infrastructure

Coordinator
SCIONLab Overview

Global Infrastructure

Inter-continental routing infrastructure
- Path diversity
- Rich connectivity
- Reliable communication
- Distributed attachment points

Coordinator

User Infrastructure
SCIONLab Overview

Global Infrastructure

User Infrastructure

Coordinator

SCION native link
IP overlay
SCION/IP redundant links
SCIONLab Overview

Global Infrastructure

User Infrastructure

Logically centralized orchestration
• Web-based configuration interface
• Automated AS and connectivity management using Ansible
• https://www.scionlab.org
**SCIONLab Overview**

**Global Infrastructure**

**User Infrastructure**

**Fully provisioned user AS**
- **Bring Your Own Computation (BYOC):** users create ASes on their machines and link to SCIONLab
- **Support for heterogeneous systems**
SCIONLab Overview

Global Infrastructure

User Infrastructure

Coordinator

Operators

Researchers

Automatically linked to SCIONLab
• IP overlay for public addresses
• OpenVPN-based tunneling for private addresses
SCIONLab Overview

Global Infrastructure

User Infrastructure

Applications
- Control Plane
  - BS
  - PS
  - CS

Routing Policy

Data Plane
- Border Router
- SCION Transport Proto.

OpenVPN

Fully configurable routing policy
- Path exploration
  - Path propagation and registration
- Path resolution
  - Number of paths, path disjointedness, etc.

Operators

Researchers

Web Interface

JoinRequest
Welcome to SCIONLab

SCIONLab is a global research network to test the SCION next-generation internet architecture.

You can join the SCION network with your own computation resources and can set up and run your own autonomous systems (ASes). Your ASes will actively participate in routing in the SCIONLab network and enable realistic experimentation with the unique properties of the SCION architecture.

Join SCIONLab  Login

About SCION

SCION (Scalability, Control and Isolation on Next-generation Networks) is an inter-domain network architecture, designed to provide route control, failure isolation, and explicit trust information for end-to-end communication.

SCION organizes ASes into groups of independent routing planes, called isolation domains (ISDs), which interconnect to provide global connectivity. ISDs naturally provide isolation of routing failures and misconfiguration, give endpoints strong control for both inbound and outbound traffic, provide meaningful and enforceable trust, and enable scalable routing updates with high path freshness.

As a result, the SCION architecture provides strong resilience and security properties as an intrinsic consequence of its design. Besides high security, SCION also provides a scalable routing infrastructure, and high efficiency for packet forwarding.

SCION is a path-aware architecture: end hosts learn about available network path segments, and combine them into end-to-end paths that are carried in packet headers. Thanks to embedded cryptographic mechanisms, path construction is constrained to the route policies of ISPs and receivers, offering path choice to all the parties: senders, receivers, and ISPs. These features also enable multi-path communication, which is an important approach for high availability, rapid failover in case of network failures, increased end-to-end bandwidth, dynamic traffic optimization, and resilience to DDoS attacks.

SCION is designed to interoperate with the existing networking infrastructure. Deployment of SCION can utilize existing internal routing and forwarding infrastructure of an AS, and only require installation or upgrade of a few border routers. A SCION-IP-Gateway (SIG) in the local infrastructure allows legacy end hosts and applications to be unaware of SCION.

Please refer to the SCION Architecture main page for more information.

About SCIONLab

SCIONLab is a global research network to test and experiment with the SCION Internet architecture. As a participant of SCIONLab, you will be able to create your own ASes that actively participate in the SCION inter-domain routing. Your AS will be running on your own hardware, under your full control.

The architecture of SCIONLab comprises a network of globally connected ASes. A number of SCIONLab ASes are configured to act as "Attachment Points", and you can choose one as the uplink for your AS. The link between your AS and the attachment point AS is established as an overlay link over the legacy Internet.

The SCIONLab website serves to simplify and coordinate the setup of experimental ASes. Once created and configured in the SCIONLab website, you will be able to download the bundled configuration files for the SCION services and run your AS. Please refer to the Tutorials for setup instructions.
Brief History of SCIONLab

- **2016**: Switzerland ISD initiated
- **2017**: N. America, EU ISDs joined
- **2018**: S. Korea ISD joined, Singapore ISD joined, AWS Backbone initialized
- **2019**: China ISD joined, Japan ISD joined, Taiwan ISD joined
- **2020**: Israel ISD joined, KREONET joined, GEANT, DFN, Fed4Fire joined, Australia ISD joined, China ISD joined, Taiwan ISD joined, AWS Backbone initialized
1st Generation: Initial Infrastructure

- Started as a *Proof-of-Concept* of SCION network
  - Single ISD with three ASes
- Few participants
  - Swisscom, SWITCH, ZKB
- Focused on building infrastructure
  - Control-plane only
- Expanded to 4 ISDs after one year
  - Swiss, EU, N. America, and Asia
  - Achieving connectivity across northern hemisphere
2nd Generation: Coordination Service

- Allowing users to create SCIONLab ASes and join SCIONLab
  - By simply filling a few necessary information (network setting / machine type)
  - One click download and installation
  - https://www.scionlab.org
- Email verification system for the coordination service
  - User verification
- Notification system
  - Notify users of released updates, breaking changes, etc.
  - Status of Join and Connection requests
- Automatic update for SCIONLab nodes
  - Fully automated update procedure
  - Updating live SCIONLab ASes every 12 hours (on bootup update for pending ASes)
- Image builder for various platforms
Thanks to the dedicated lines that AWS provides, backbone ISD provides higher path diversity and better path quality.
Global research networks improve SCIONLab backbone

**Korea Research Environment Open Network 2**
- 10 - 100Gbps high-speed research network
- Started from GLORIAD project (Global Ring Network for Advanced Applications Development)
- Interconnected with more than 35 global research networks across the world
  - GÉANT, Internet2, CERN, etc.

**GEANT: European research & education network**
- 10 - 100Gbps high-speed research network
- Connecting 50M users in over 10K institutions
- Reaches more than 100 countries worldwide

**Fed4FIRE: Federation of NGI testbeds**
- Access to >16 testbeds (ExoGENI, Grid5000, etc.)
PERFORMANCE EVALUATION
83% of node pairs show tolerable latency overhead:

\[ \text{RTT}_{\text{diff}} \leq 5 \text{ ms.} \]
Network Latency Inflation: Multi-hop Communication

- Apx. 33% of node pairs show better latency
Better latency for majority of high-latency node pairs
Aprox. 60% of paths show an alternative path with:

\[ \frac{d_a}{d_s} \leq 1.4 \]
Packet Forwarding Performance

- Less than 20 μs of packet processing time for over 90% of cases (10.17 μs on average)
More in the Paper

Details about implementation and deployment

- Implementation on heterogeneous systems
- Large-scale ISP deployment

More experiments

- Microbenchmarks
- Control-plane scalability

Lessons we have learned as an operator

- Operational insights and challenges
- Long-term viability

Ongoing research projects

- New research topics leveraging SCIONLab
Interested to join the SCIONLab Network?

Join as User AS

- You want to simply try out or do **exciting research experiments** with a full fledged SCION AS
- You want to connect to SCIONLab in less than 10 minutes and **few clicks only**
- You don't have any specific hardware available, other than your laptop (with VirtualBox)

Join as Infrastructure AS

- You intend to run your SCION AS 24/7
- Your border router can have a public static IP address
- Your firewall can be configured to meet the SCIONLab connectivity requirements
- You want to be eligible for a PC Engine device

➡️ https://www.scionlab.org/
Thank you for your attention!

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