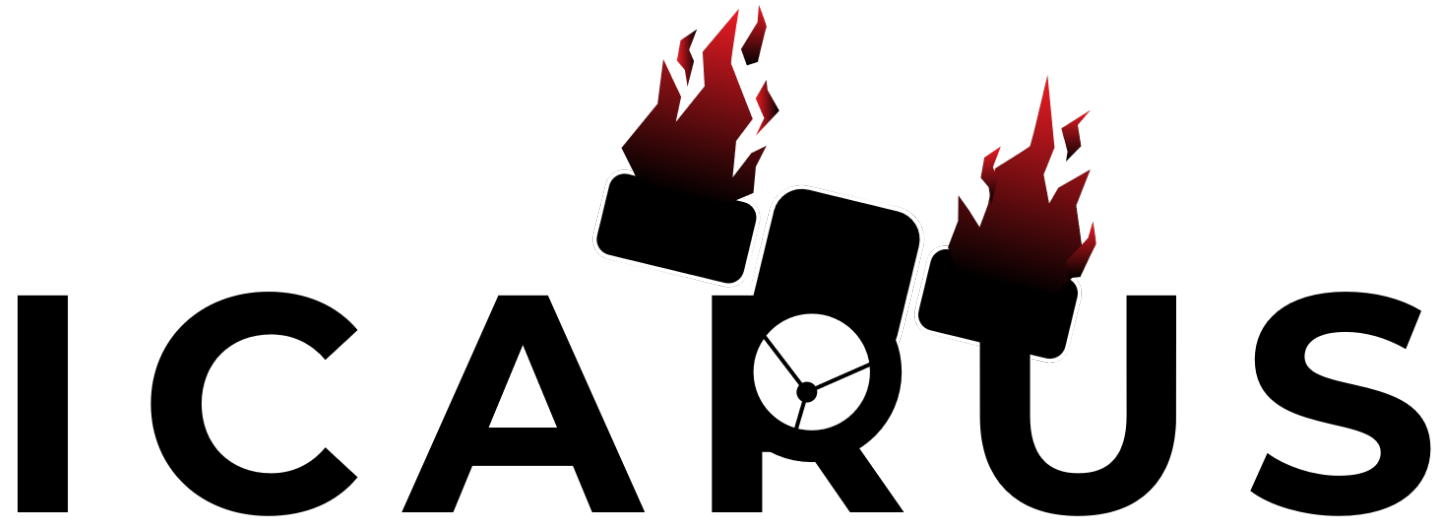
ETH zürich

Network Security Group



Attacking LEO satellite networks

Giacomo Giuliari, Tommaso Ciussani,
Adrian Perrig, Ankit Singla
ETH Zurich
10 June 2021, USENIX ATC 21

STARLINK SPEED TESTS —

SpaceX Starlink speeds revealed as beta users get downloads of 11 to 60Mbps

Ookla tests aren't showing the gigabit sp

JON BRODKIN - 8/14/2020, 7:00 PM

Starlink Blazes Past 560 Mbps In Download Spee Shows Latest Test Run!

By Ramish Zafar

May 17, 2021 12:37 EDT

SpaceX's Satellite Internet Service Latency Comes in Under 20 Milliseconds

SpaceX disclosed the benchmarks in a presentation the company sent to the FCC last Friday. It also revealed the public beta for Starlink is coming to multiple US states.

By Michael Kan 9 Sep 2020, 8:04 p.m.

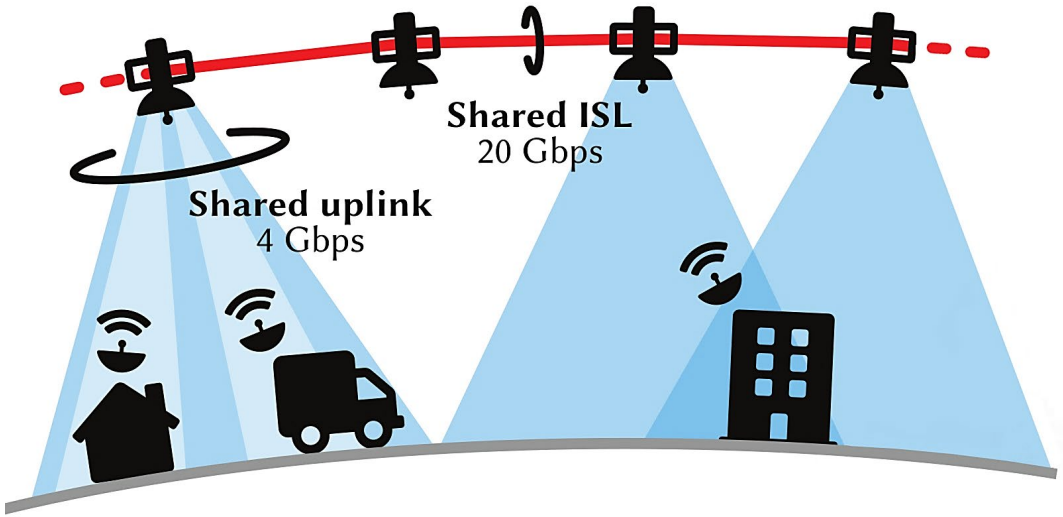
Starlink is asked to increase the number of users from 1 million to 5. Their services are in "incredible demand"

In the US alone!

BY JOHN KESSLER AUGUST 3, 2020 10:39 PM GMT+0300

536 VIEWS

How is this achieved? **The network model**

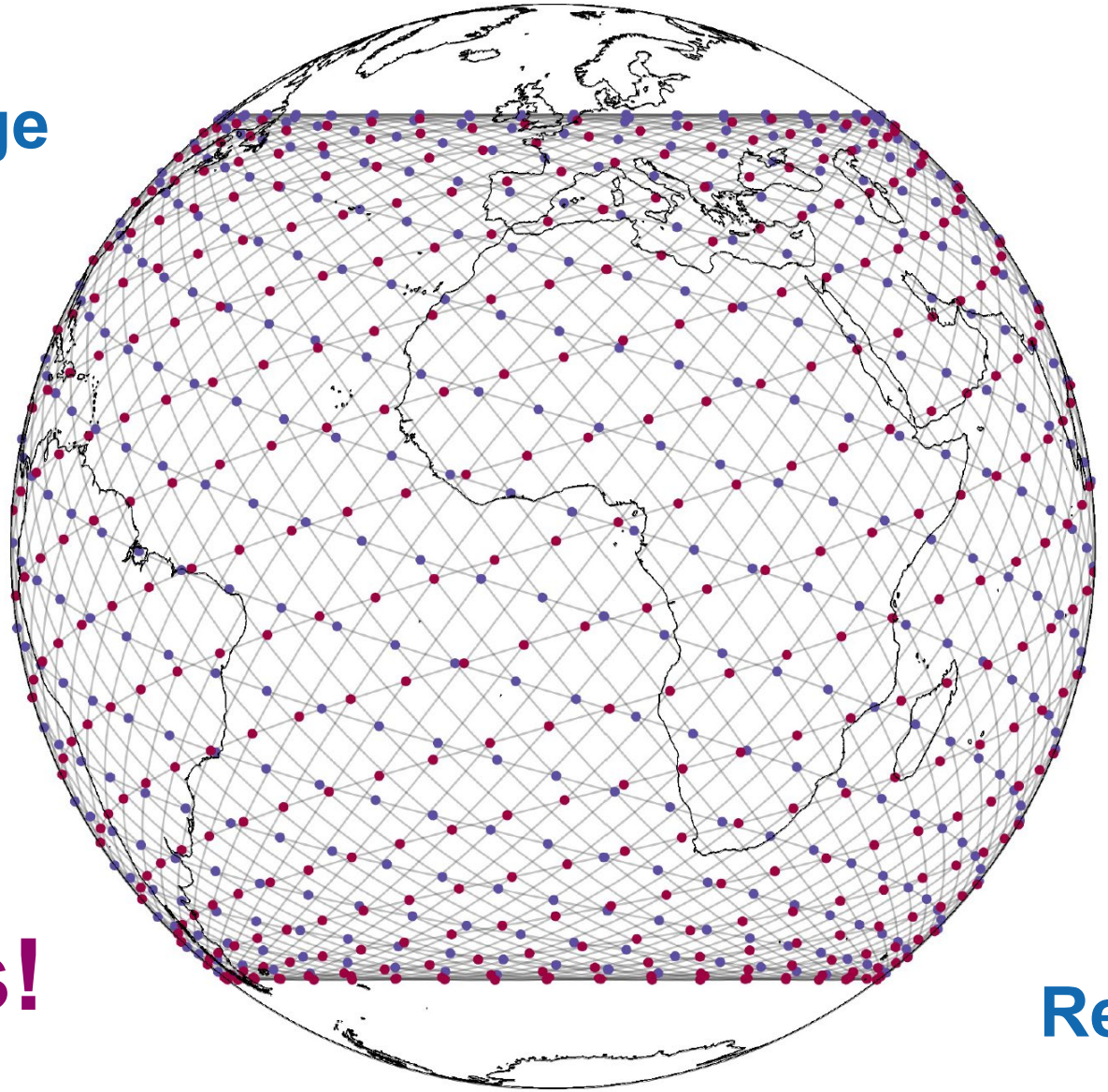


- **Uplinks and downlinks**
  - Can serve multiple hosts
  - 4 Gbps upload for each uplink
  - Reconfigure as satellites move
- **Inter-satellite links**
  - Can carry up to 20 Gbps
  - High-capacity network in space
- **Low latency advantages**
  - The speed of light in vacuum is 50% faster than in fiber
  - Paths over ISL are straighter than fibers

SpaceX Starlink Shell 1

Global coverage

Low latency



FinTech

Remote AR

Cloud gaming

Remote surgery

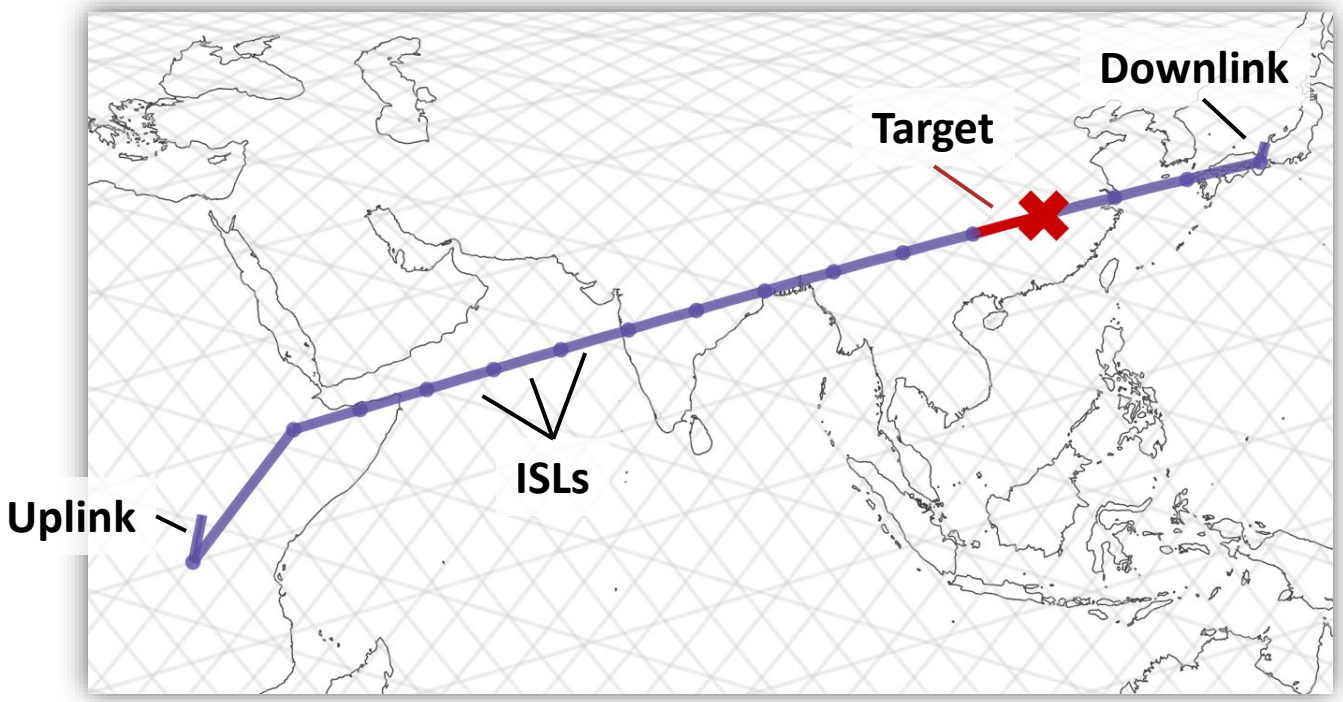
Not just rural areas!

This tremendous potential generates great interest around LSNs…

…an interest shared by adversaries

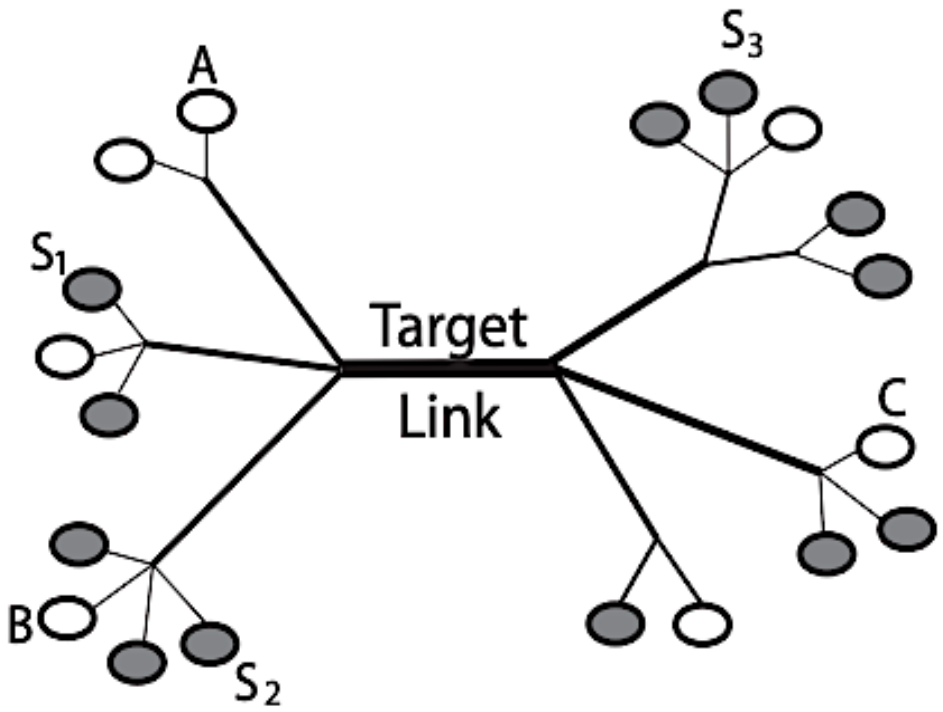
How can they disrupt an LSN?

The ICARUS attack



- Adversarial goal: **disrupt communication between hosts** over the satellite network
- We do not consider **known attacks**
  - **Jamming** uplinks and downlinks
  - Attacks on weak (inexistent) encryption
- Adversaries can exploit LSN characteristics
  - In this presentation: **attacks on ISLs**
  - High disruptive power many flows use the same ISL

Starting point: the **Coremelt DDoS attack**



- Instead of attacking a specific end host, **we attack a network link**
  - Flows between different **src-dst pairs**
  - **Flows imitate legitimate traffic**
  - **“There is no victim”**

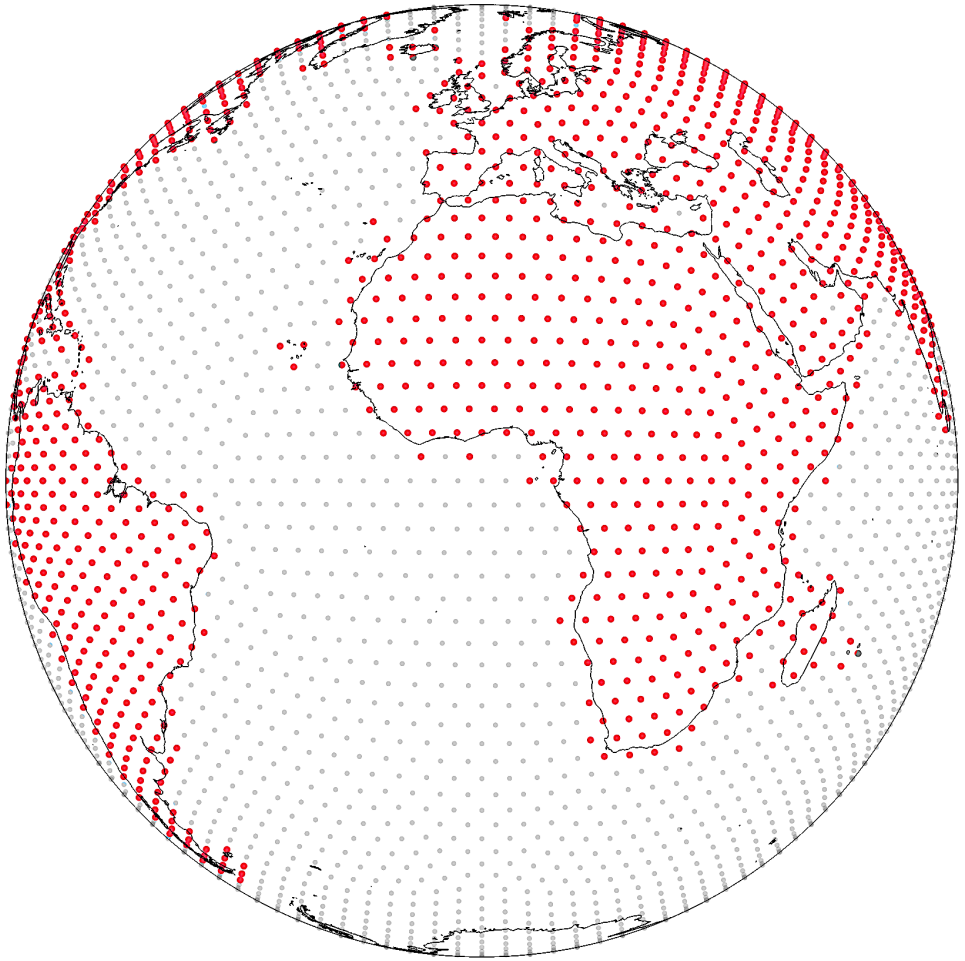
High resilience to detection

Can Coremelt be applied to LSNs?

#1: **Space-based low-latency network ⇨ Predictability**

- **“White Box” network**
  - Public satellite **positions**
  - Public satellite **designs**
- **Advance topology computation** with low error
  - < 2km / day
- **Routing policy can be discovered**
  - Latency measurements + topology knowledge
  - Single or multi-path

#2: **Global access** ⇨ **DDoS attack stealthiness**



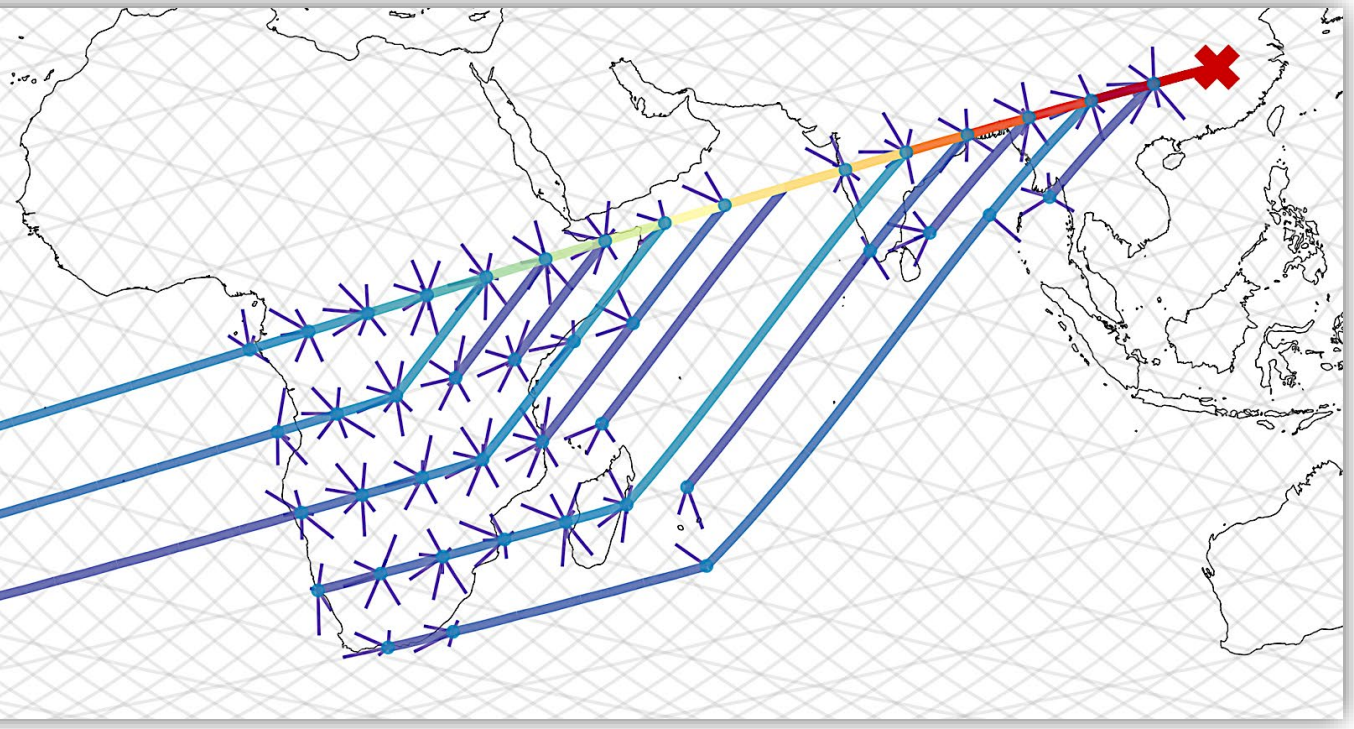
- Remote areas are connected
  - **Increased scatter** of attack sources
  - **Millions** of terminals available for compromise
- Every satellite is an **entry point to the network**
  - No distinction between border routers and backbone routers
  - Increased **attack surface**
- The adversary **knows bot location** (GNSS)

#3: **Low-latency/higher cost ⇨ Tight operation margins**

- There is a **combinatorically high number of paths** between two satellites in the LSN
- **BUT** High-paying customers require **low-latency and bounded jitter**
- Of the many paths, the LSN operator can only use **desirable (low-latency) paths**

- For a successful attack **the adversary only needs to "delay" packets for long enough!**
- The adversary needs to:
  - Congest the forwarding path
  - Create buffering delay on satellites
- Even if **alternative paths are still available, the adversary is successful**

ICARUS: **Attack mechanism**

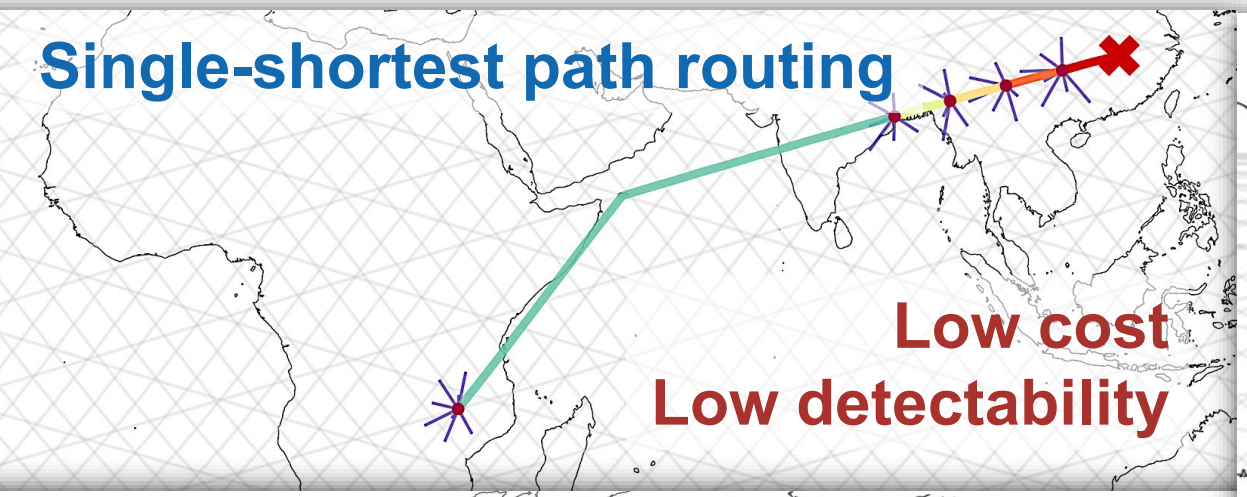


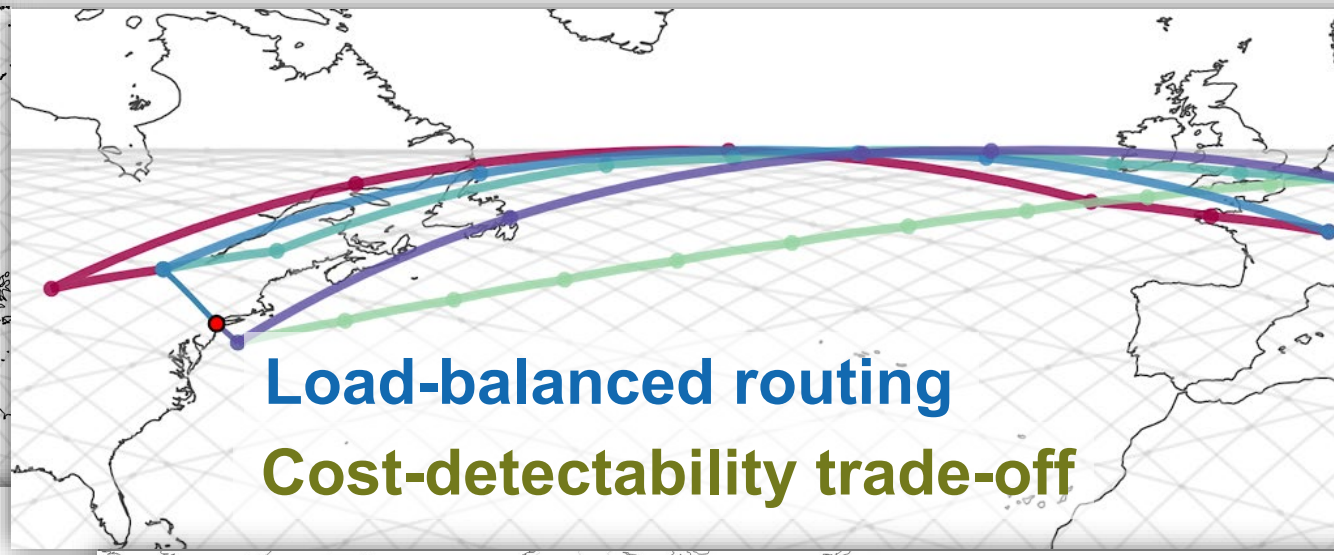
- Send **traffic flows** through the target link using:
  1. **Public knowledge of LSN topology**
  2. **Distributed access points**
  3. **Knowledge of routing**

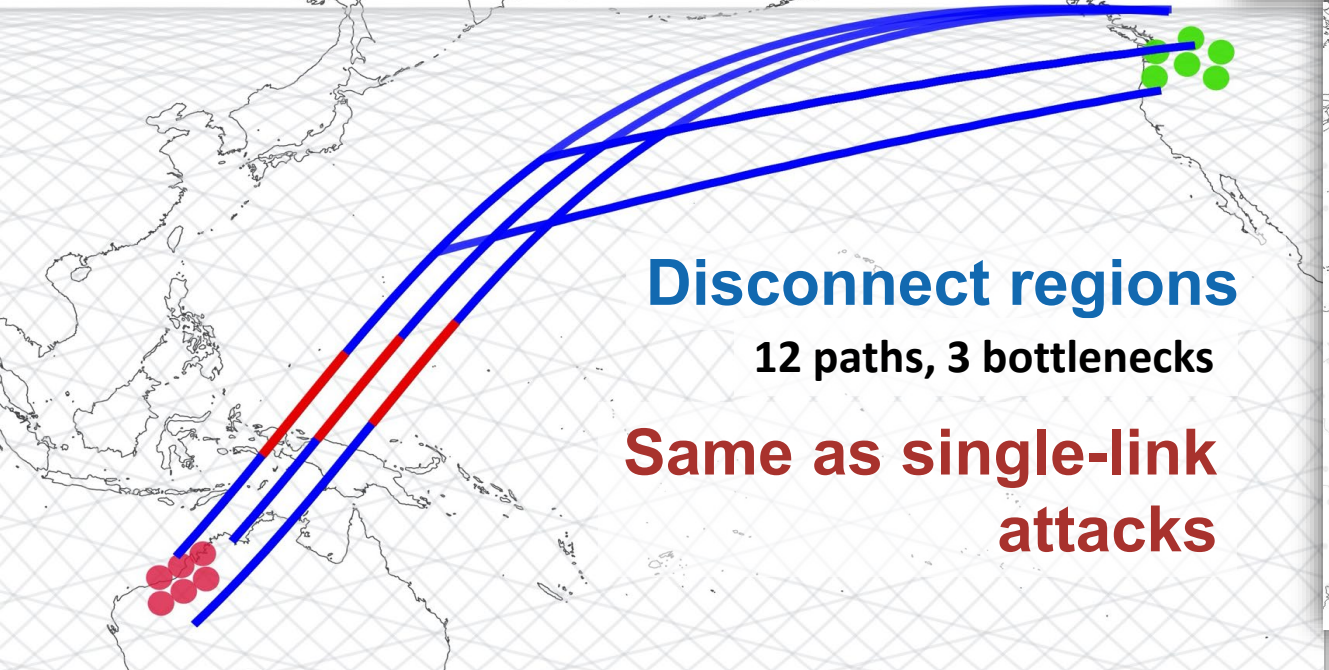
- Attack metrics:
  - **Cost = # bots needed**
  - **Detectability = max # bots on an uplink**

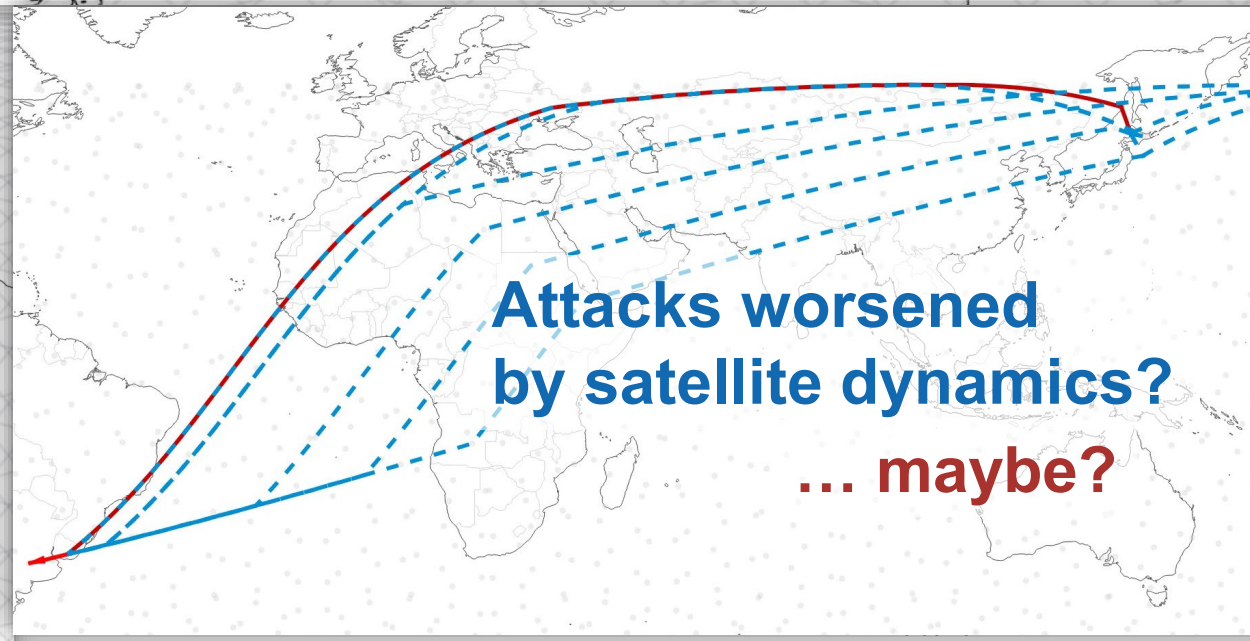
Effective attack ↔ low metrics

Satellite routing: in the paper…

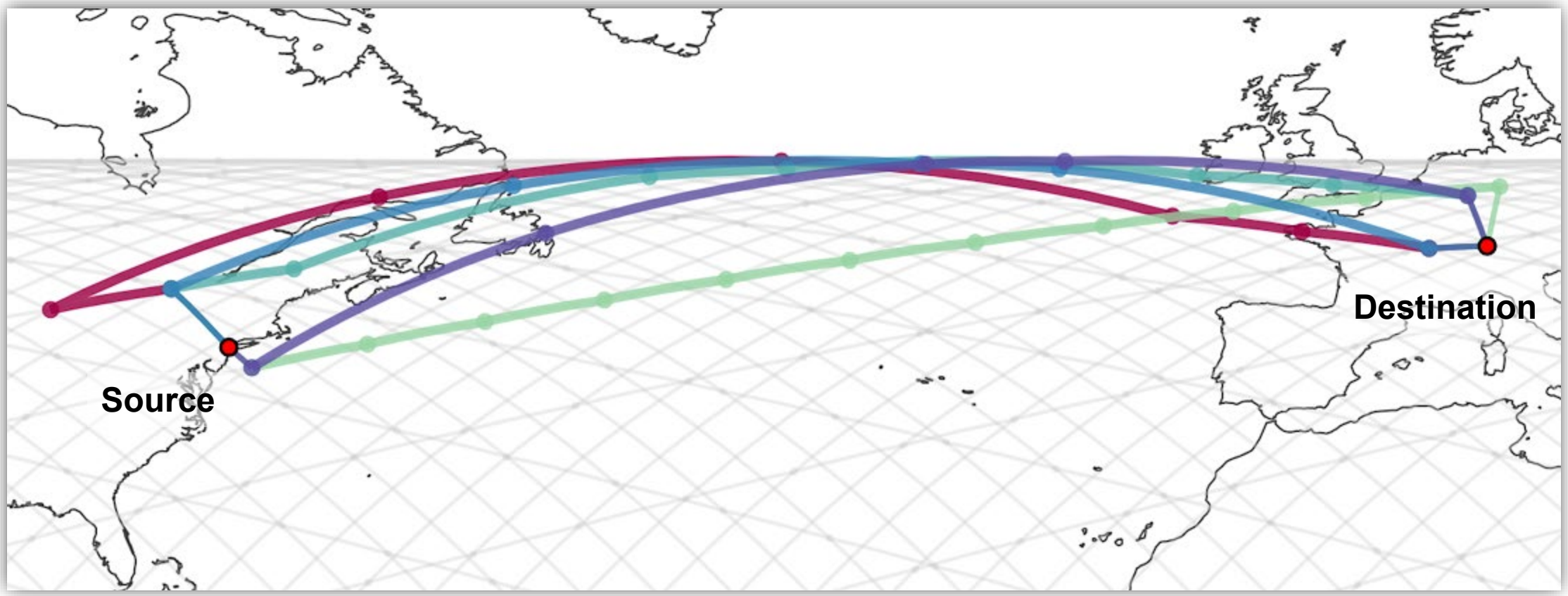






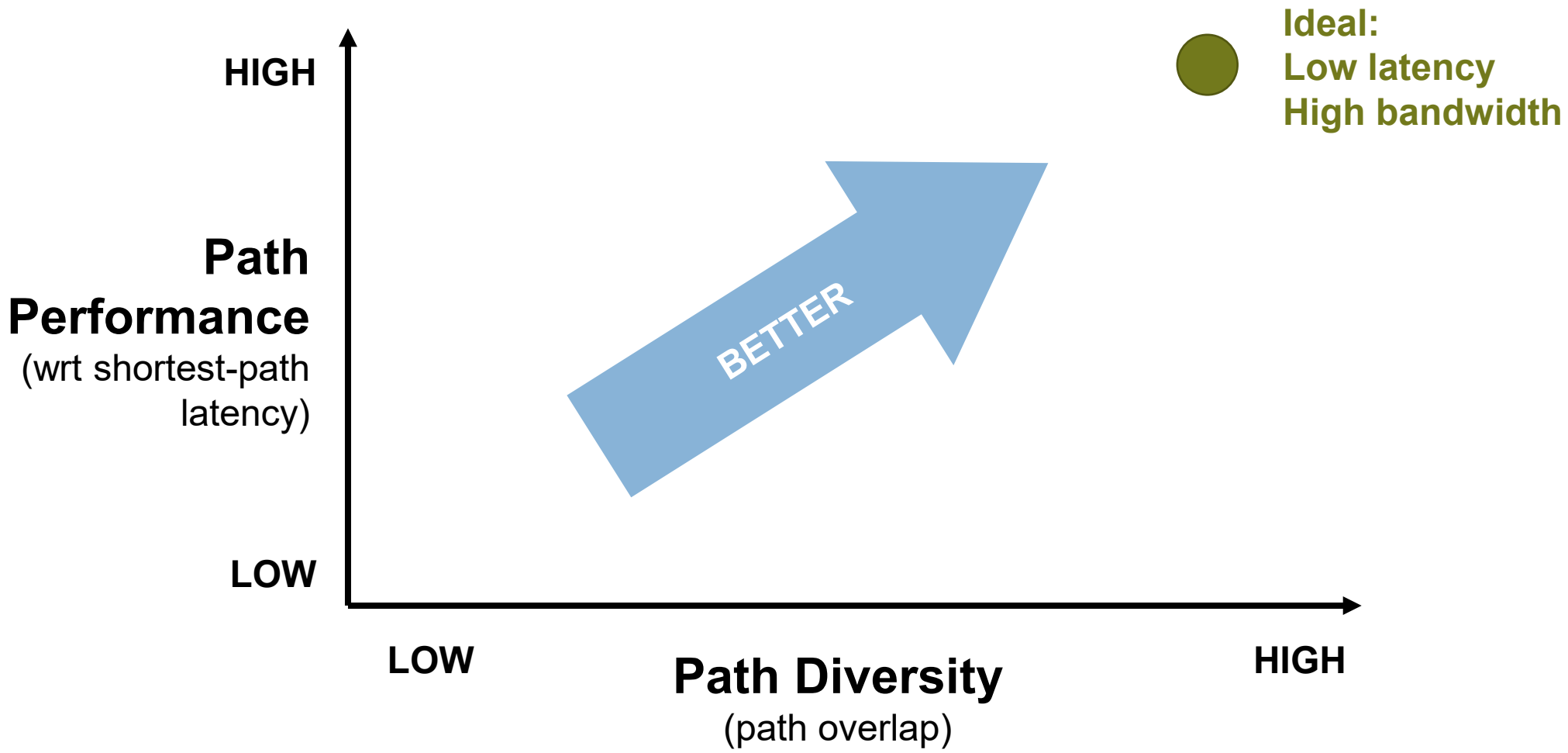


Load balancing over satellite paths

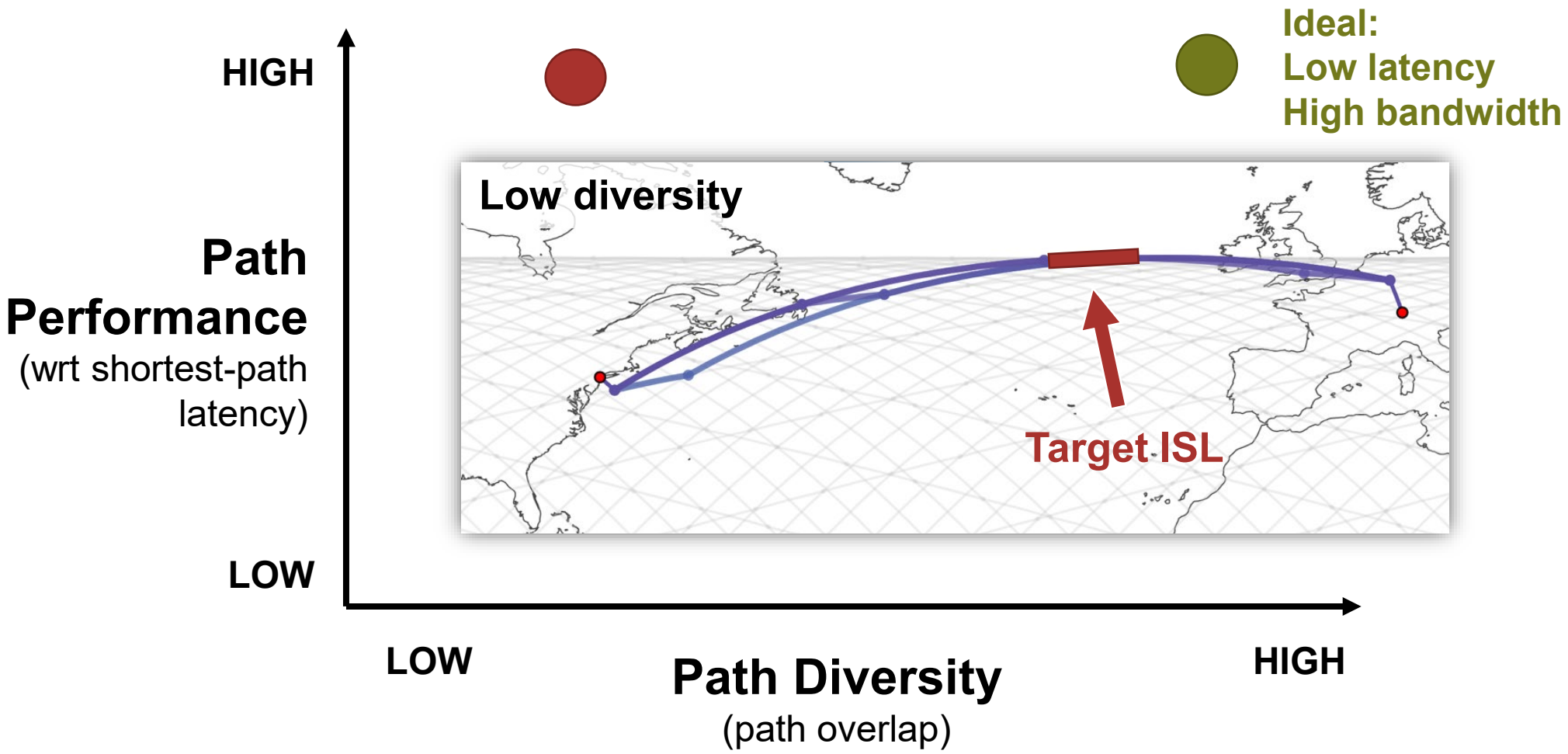


Path **chosen at random** at **forwarding time** from the **load-balancing set**

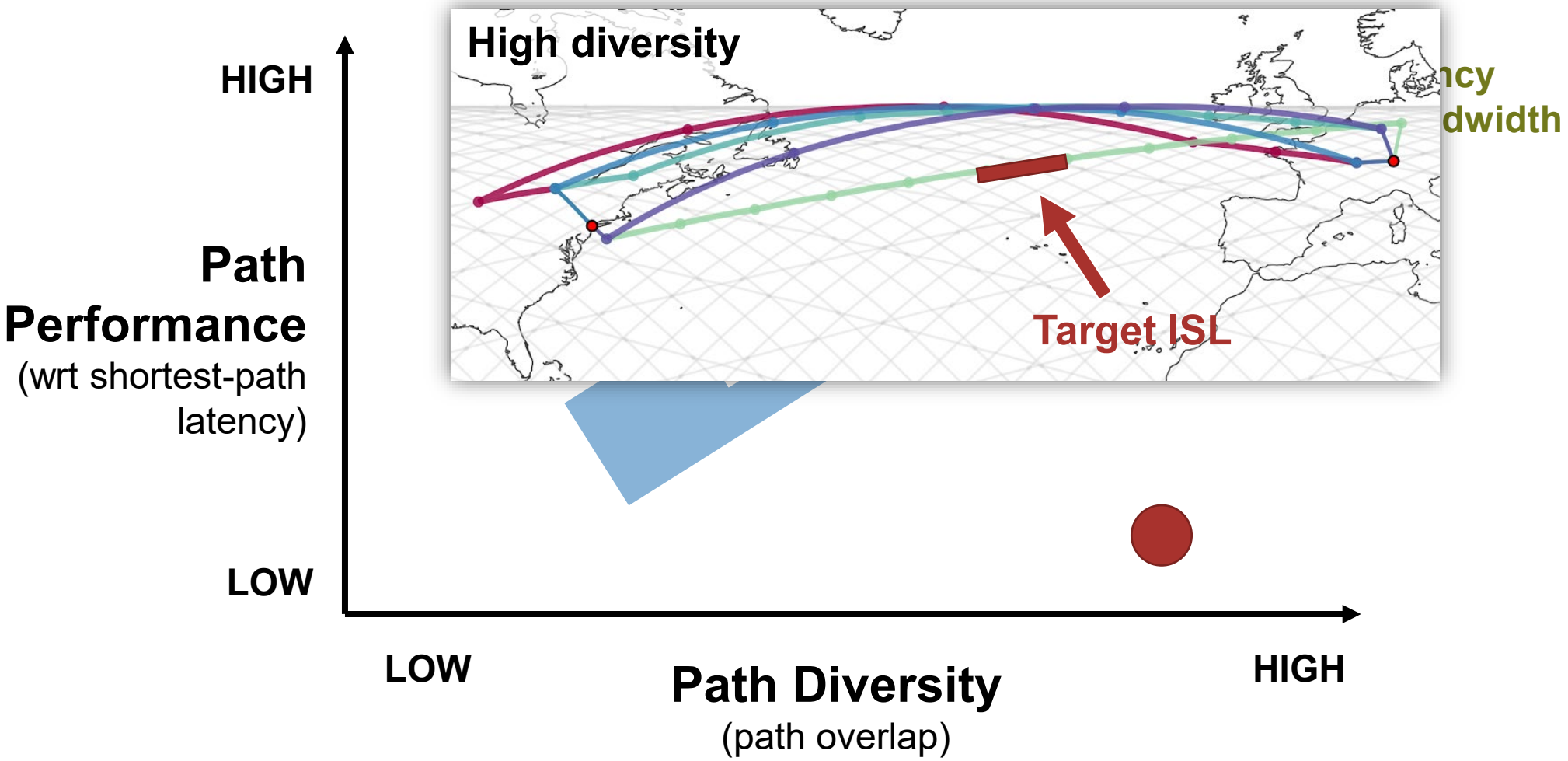
Load-balancing **design space**



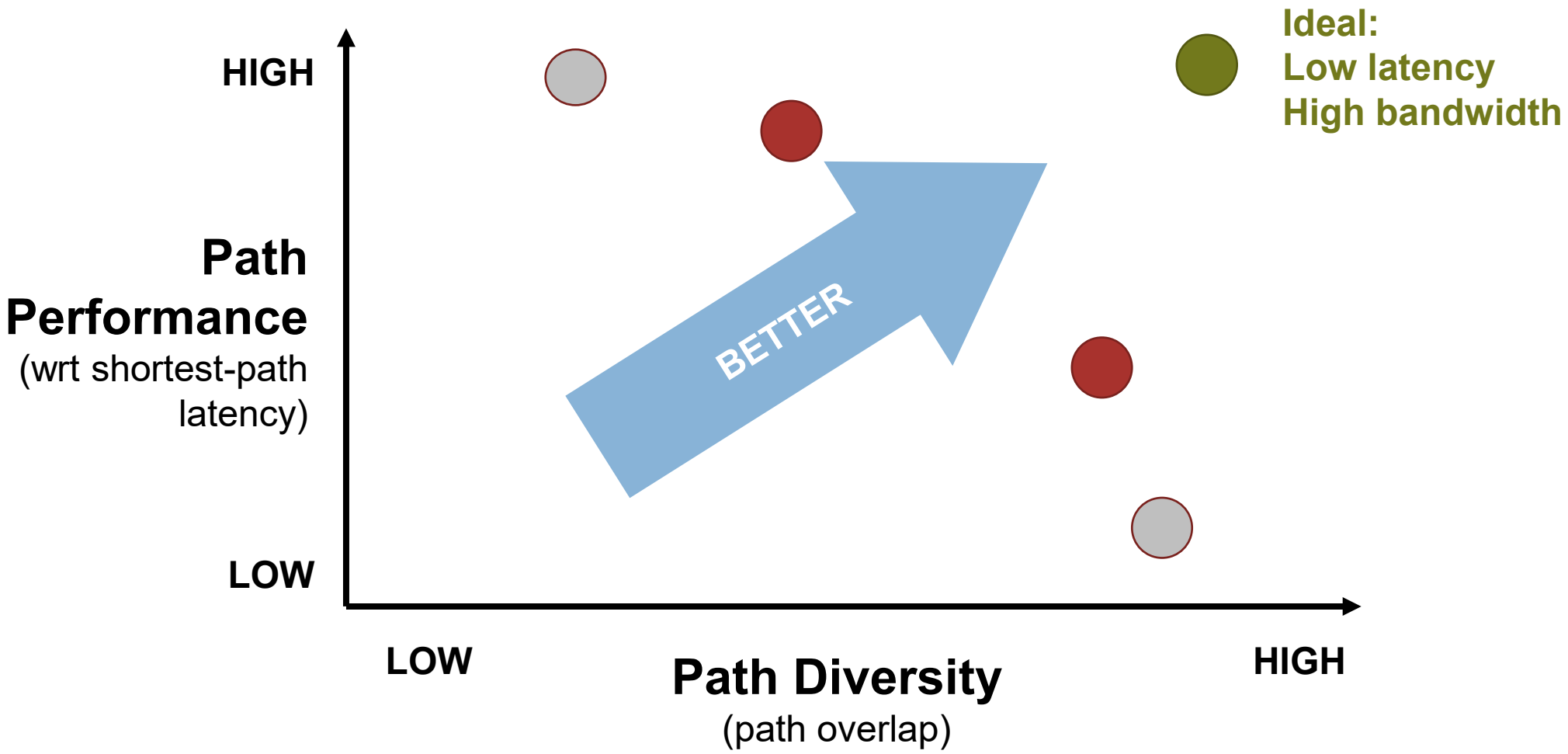
Load-balancing **design space**



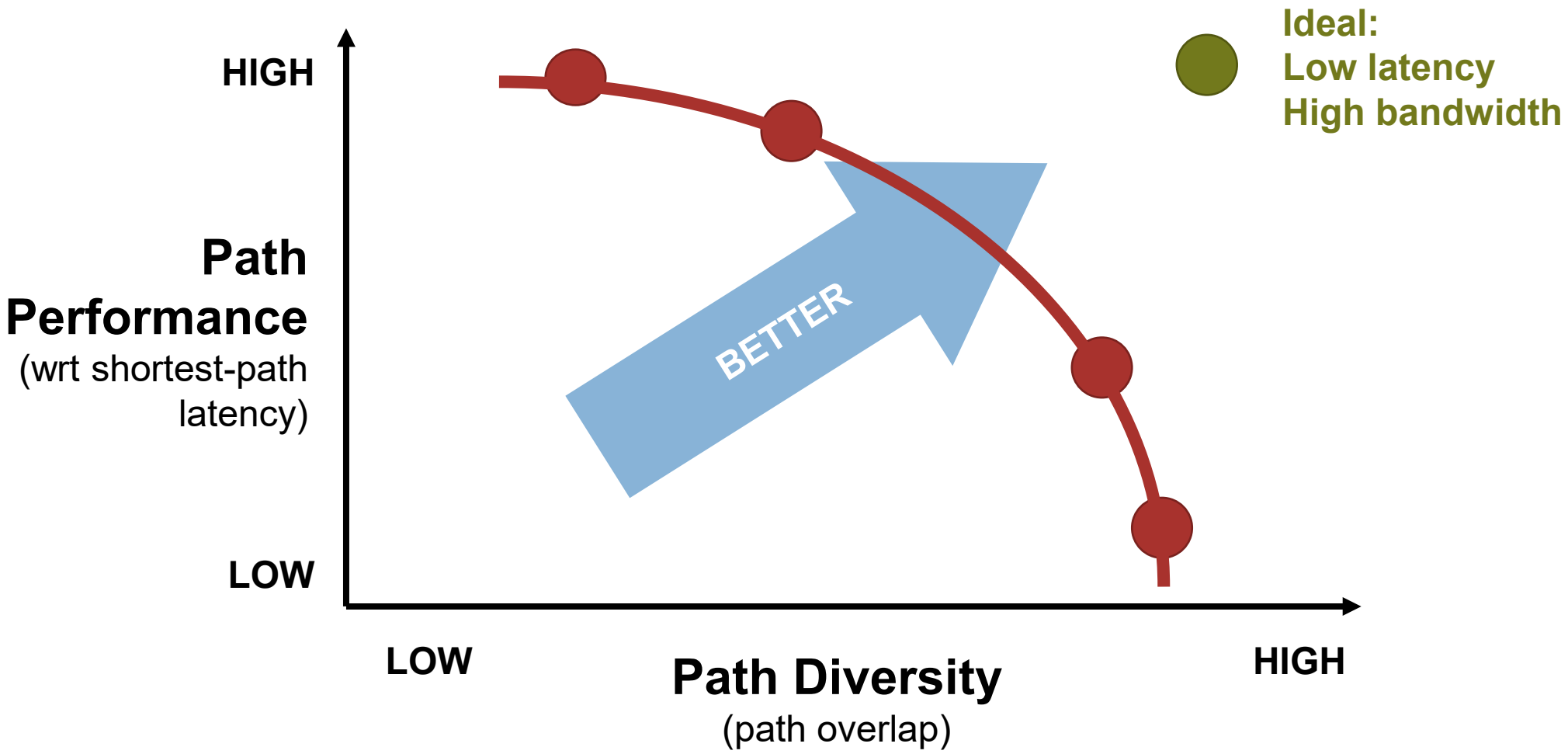
Load-balancing **design space**



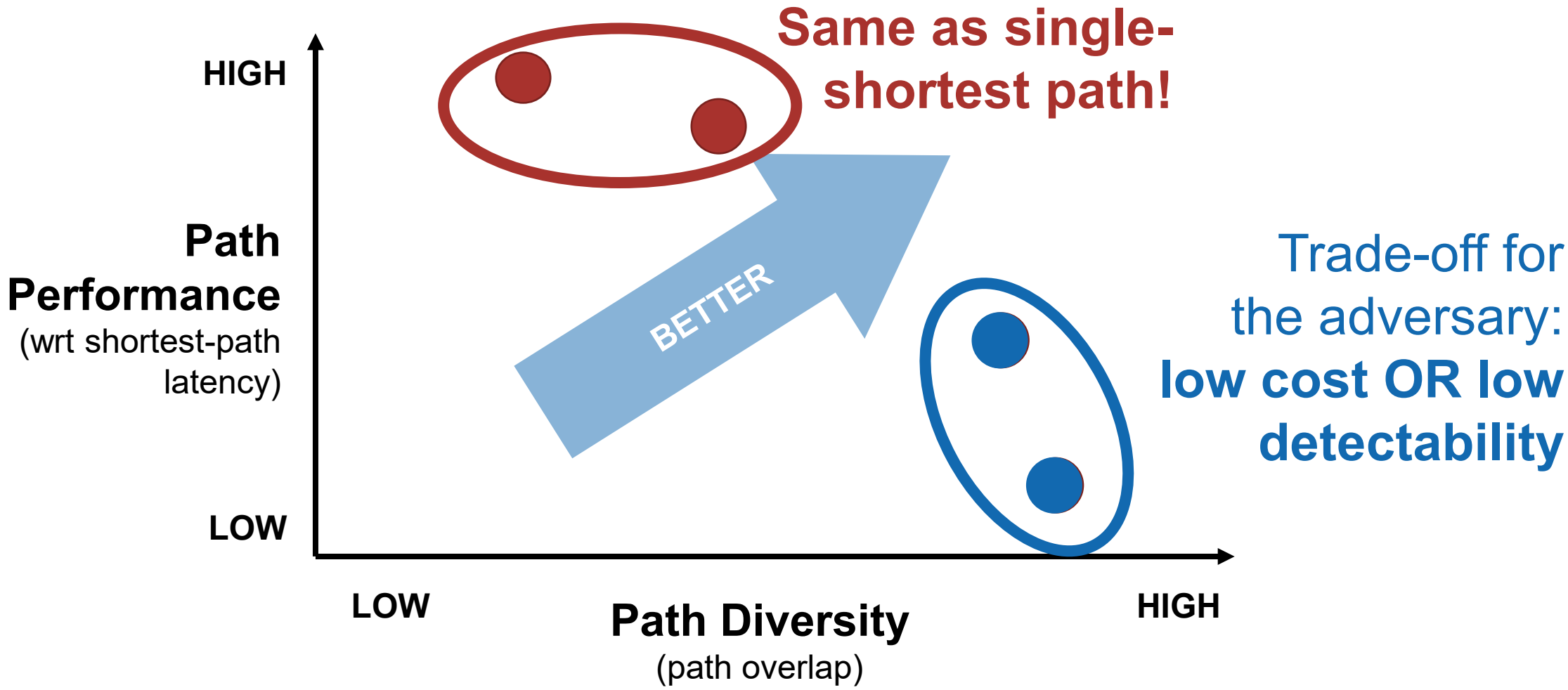
Load-balancing **design space**



Load-balancing **design space**

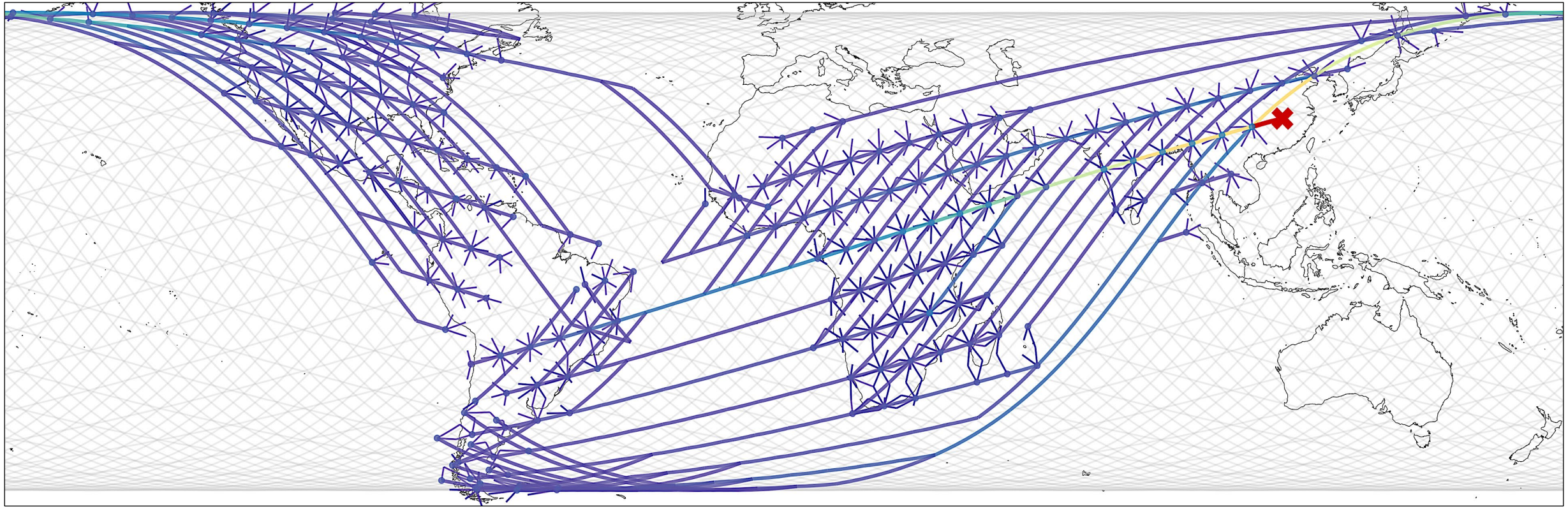


Load-balancing **effect on attacks**



Trade-off for the adversary: **low cost OR low detectability**

Probabilistic ICARUS **detectability optimization**



- **Cost:** **3.5 times** the median single-shortest path attack cost
- **Detectability:** **half** of the median single-shortest path attack detectability

Mitigations

Traditional:

Attack and legitimate flows cannot be distinguished

- Traceback systems
- Traffic filtering
- Cloud DDoS protection

LSN-oriented:

- Resilient **routing**
- Improved **topology design**
- Increase attack cost/detectability without increasing latency

Conclusions & Contributions

- **LSN network attacks are a threat**
  - Different network characteristics
  - Advantages and disadvantages for defense
- **ICARUS is powerful**
  - ~100% path attack success rate
  - Low median cost and detectability
- **Defense not trivial**
  - Attack flows not distinguishable
  - Even with **load balancing**:
    path diversity and attack resilience ⟶ latency increase
- **Future outlook**
  - **Attack:**
    - Exploit network dynamics
  - **Defense:**
    Explore resilient load-balancing policies
    Explore strong topology designs
- **Evaluation framework** for future research
  `github.com/giacgiuliari/icarus-framework`

Thank You!

Giacomo Giuliari

`giacomog@inf.ethz.ch`