TANGO: Secure Collaborative Route Control across the Public Internet

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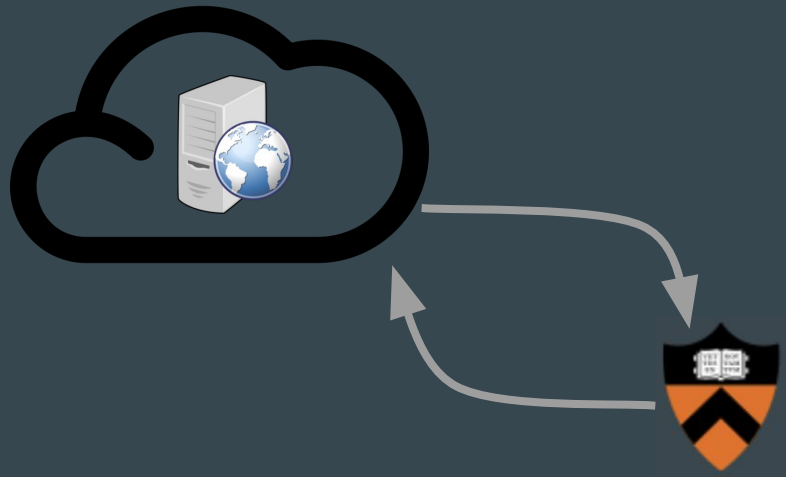
Is today's Internet good enough for performance-critical applications?

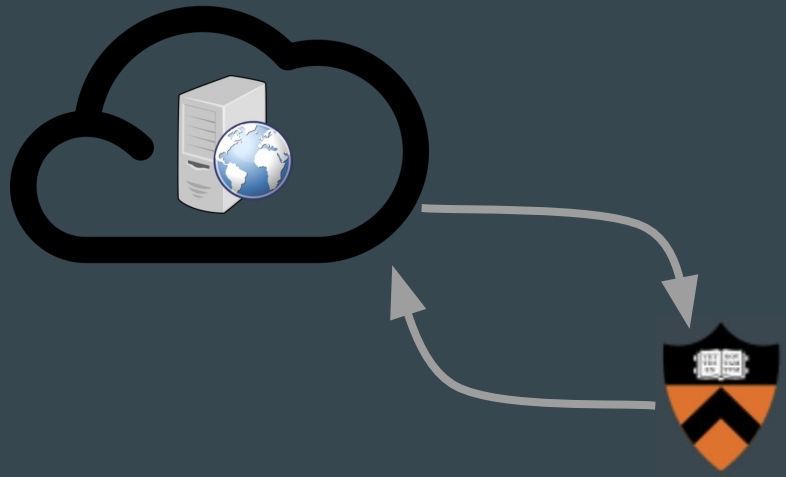
Scenario: University working with a small cloud provider

- Small cloud provider offers best price and capabilities
- Performance critical apps need to be reached from campus
- Campus and cloud communicate over the public Internet



Problem: Internet doesn't offer performance guarantees

- Latency can be too large or inconsistent
- Loss can be unacceptably high
- Reliability suffers



One Approach: Network performance is offered as a paid service!

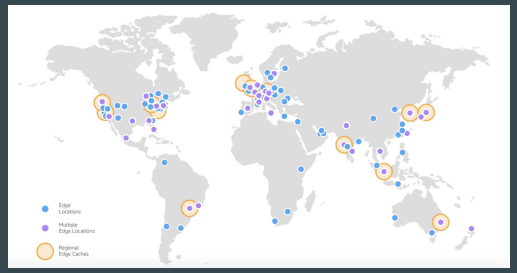
Edge computing : performance-critical services placed close to edge networks

Network-as-a-Service (NaaS) : on-demand products offering reliable, reserved bandwidth point-to-point links

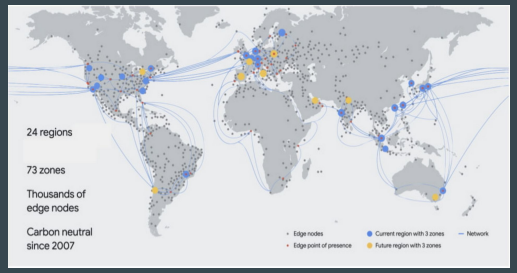
But small networks and underserved regions cannot compete

Only hypergiants can afford vast numbers of edge nodes

AWS:

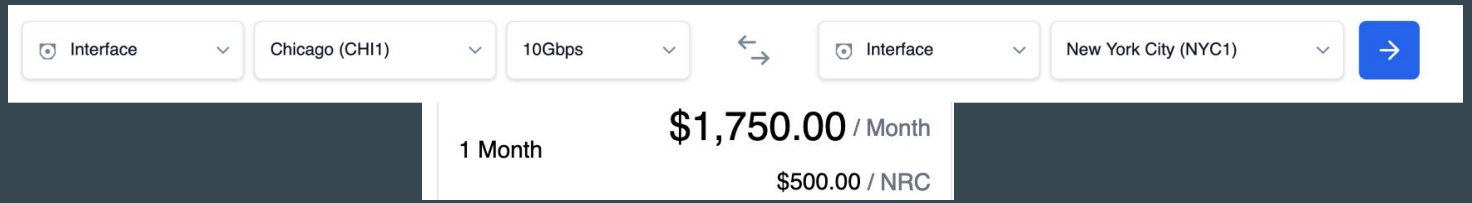


Google:



Only large organizations can afford network-as-a-service

Packet Fabric:



What would it take for the Internet to serve performance-critical apps?

- We need to know what paths are available (Path Diversity)
- We need to accurately measure performance along those paths (Measurements)
- We need to dynamically route traffic down the best path (Route Control)

Overcoming the challenges of Internet performance with Tango

Tango

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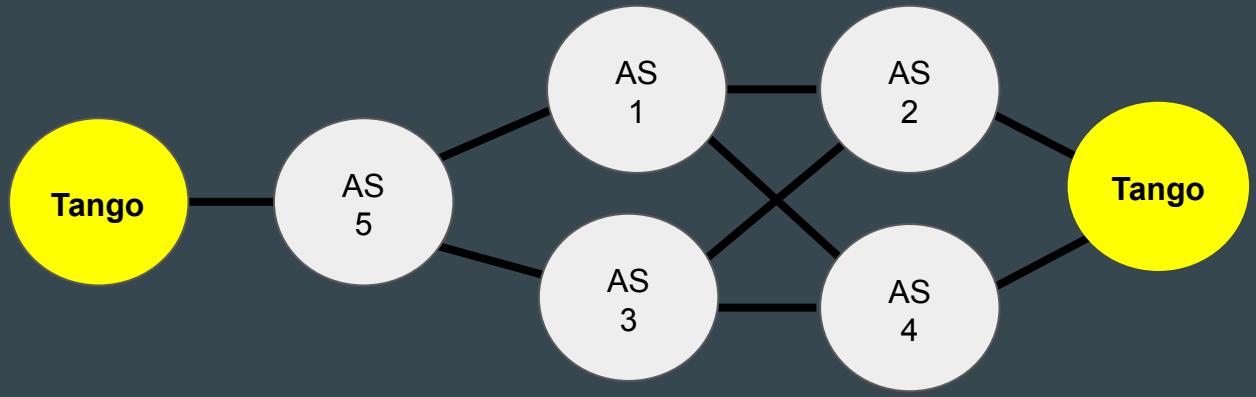
Tango

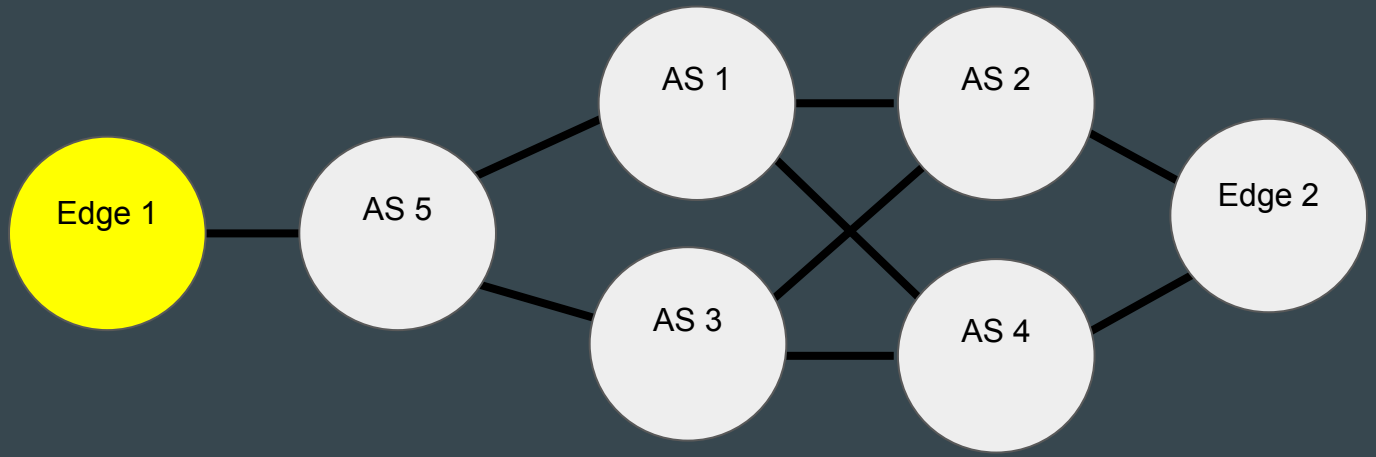


Cooperative and secure edge-to-edge routing with Tango

What would it take for the Internet to serve performance-critical apps?

- **Path Diversity** 
- Measurements
- Route Control

Why Path Diversity is hard:
Traditional Internet Routing (BGP) does not expose all paths



- Edge 1 only has a single upstream thus a single path exported by AS 5

Why Path Diversity is hard:
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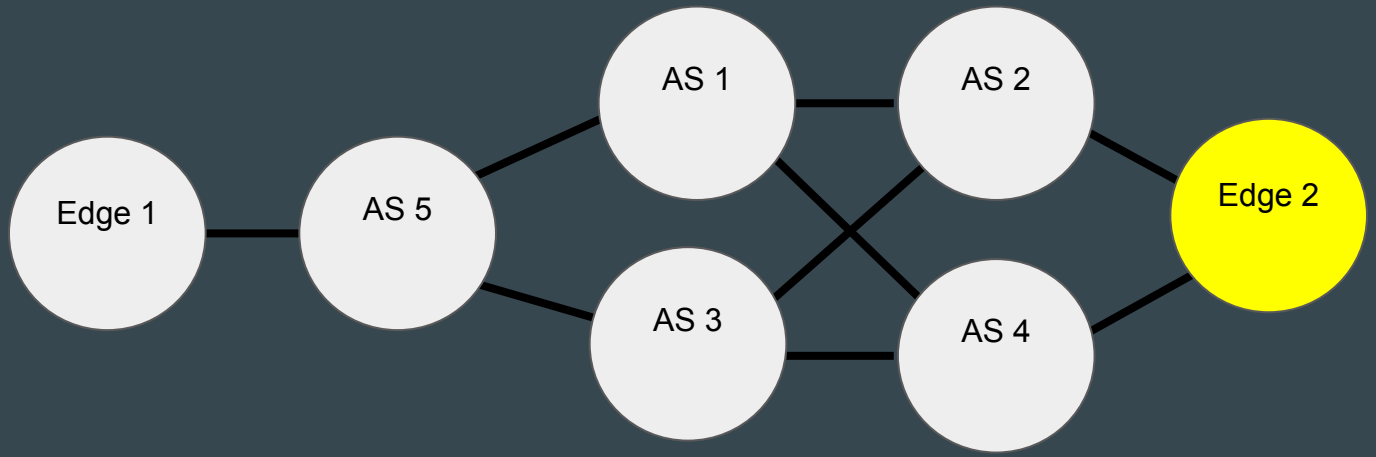


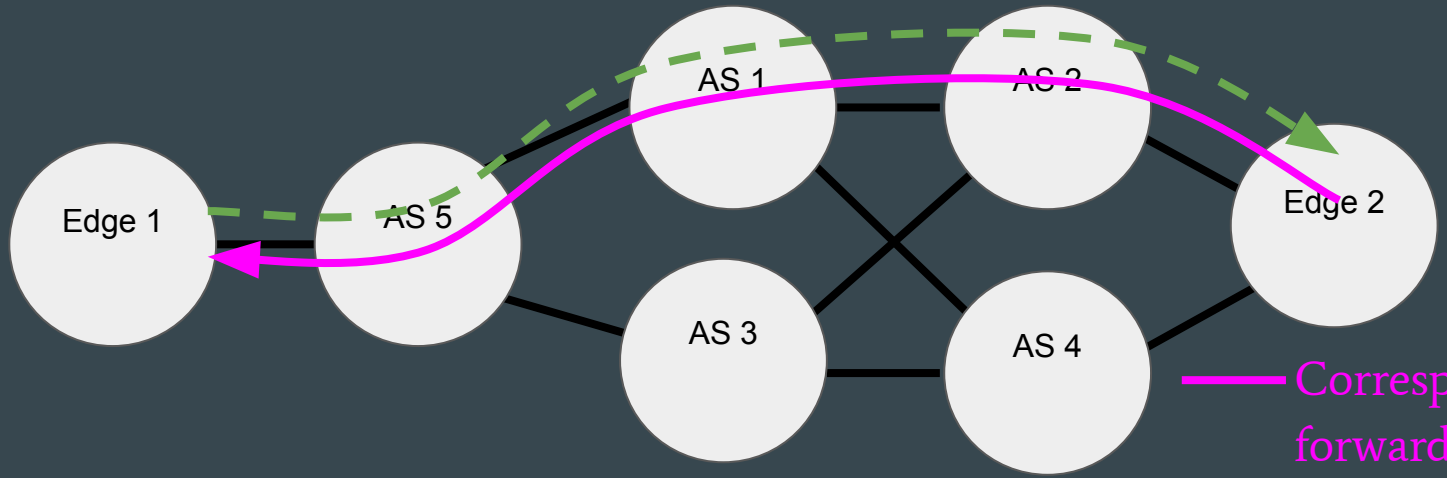
- Edge 2 is multi-homed but only influences a single hop, not the whole route

Solution: automatically exposing Path Diversity with BGP pathfinder

BGP announcement propagation
prefix: abcd:1::/48

BGP Pathfinder has no knowledge of the topology:

Begin with the default path

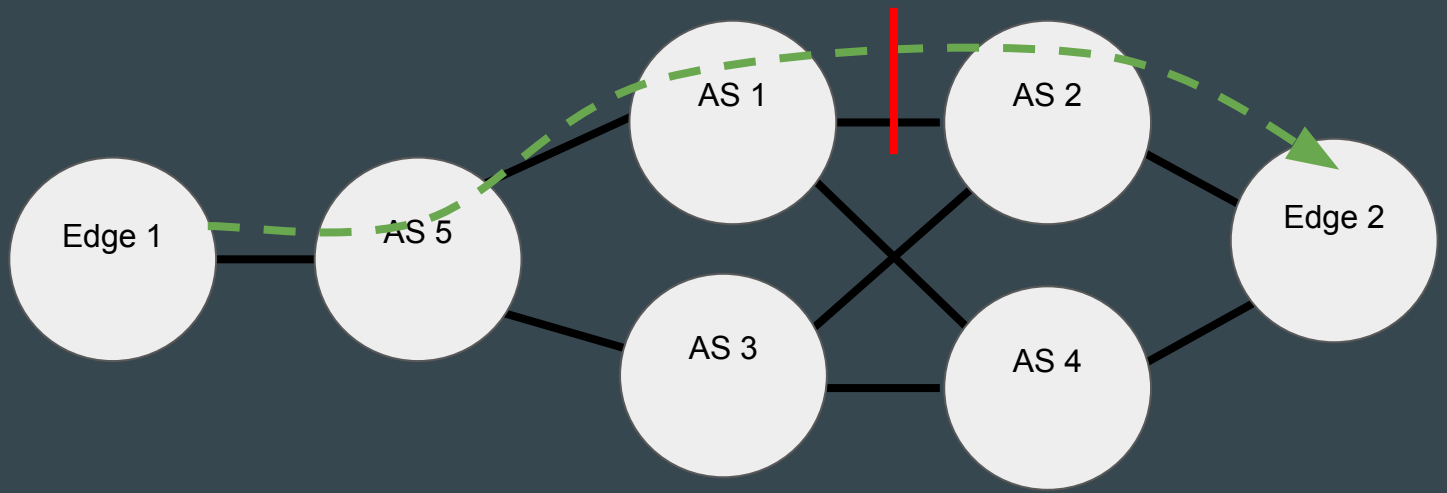


Corresponding traffic forwarding path

Solution: automatically exposing Path Diversity with BGP pathfinder

BGP announcement propagation
prefix: abcd:1::/48
communities: AS1:No_Export_to_AS2

Suppress the default path



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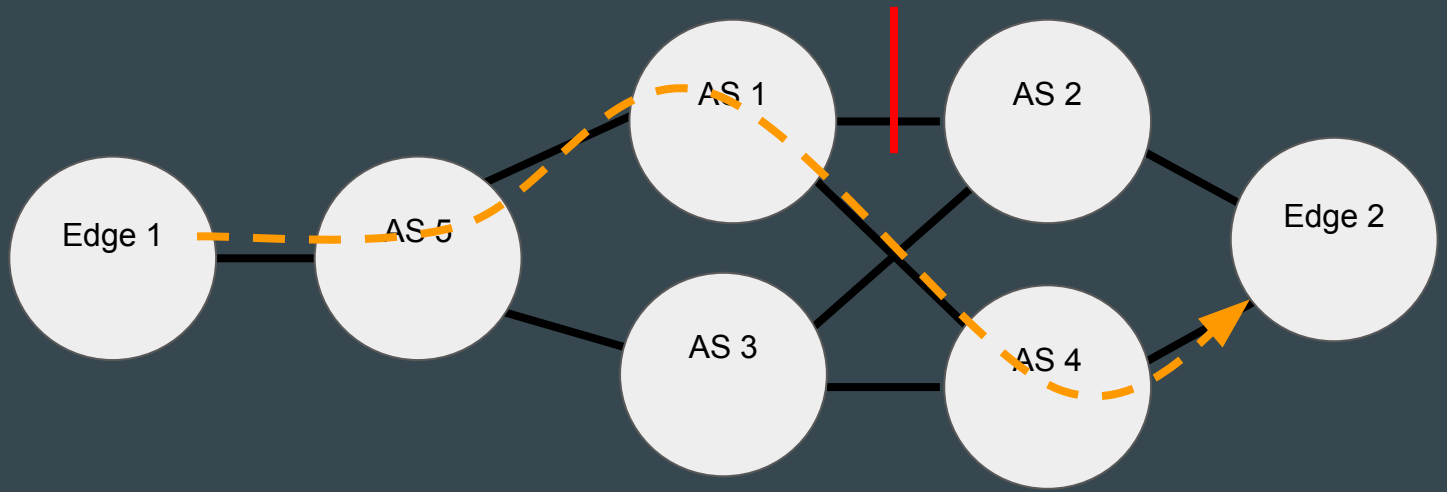
Find the next path



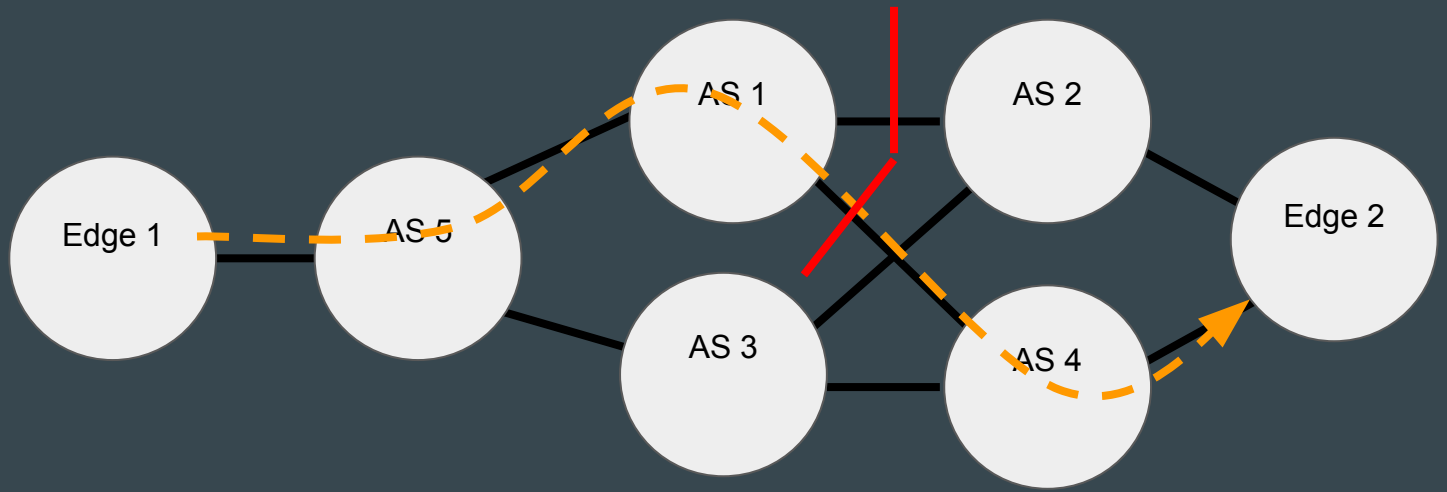
Solution: automatically exposing Path Diversity with BGP pathfinder

BGP announcement propagation

prefix: abcd:1::/48

communities: AS1:No_Export_to_AS2, AS1:No_Export_to_AS4

Suppress the new path



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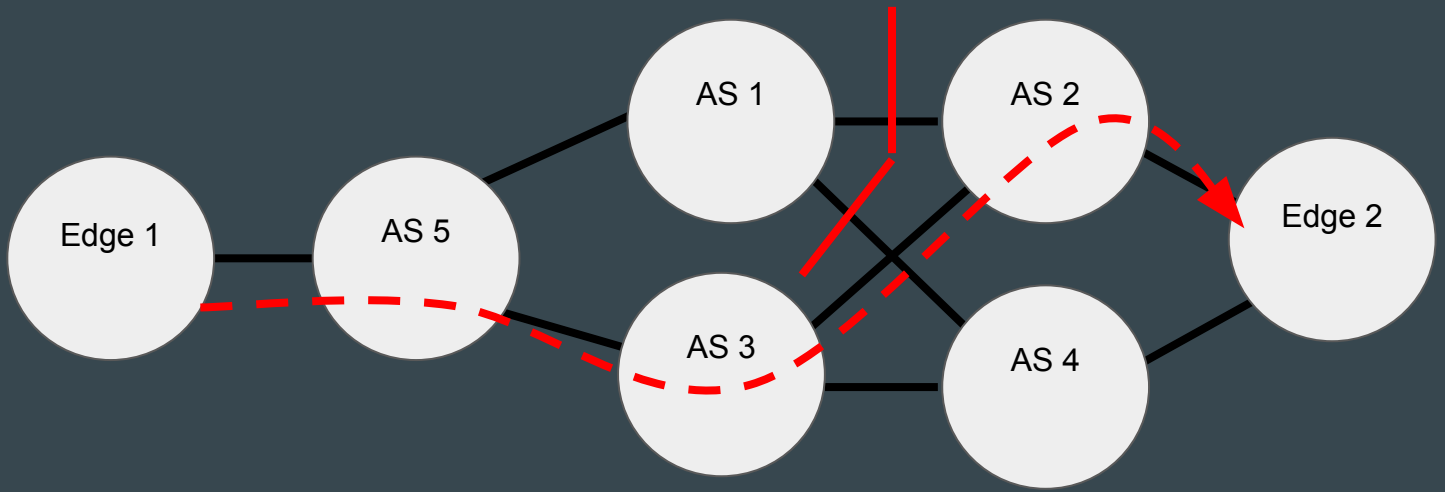
BGP announcement propagation

prefix: abcd:1::/48

communities: AS1:No_Export_to_AS2, AS1:No_Export_to_AS4

Find the next path



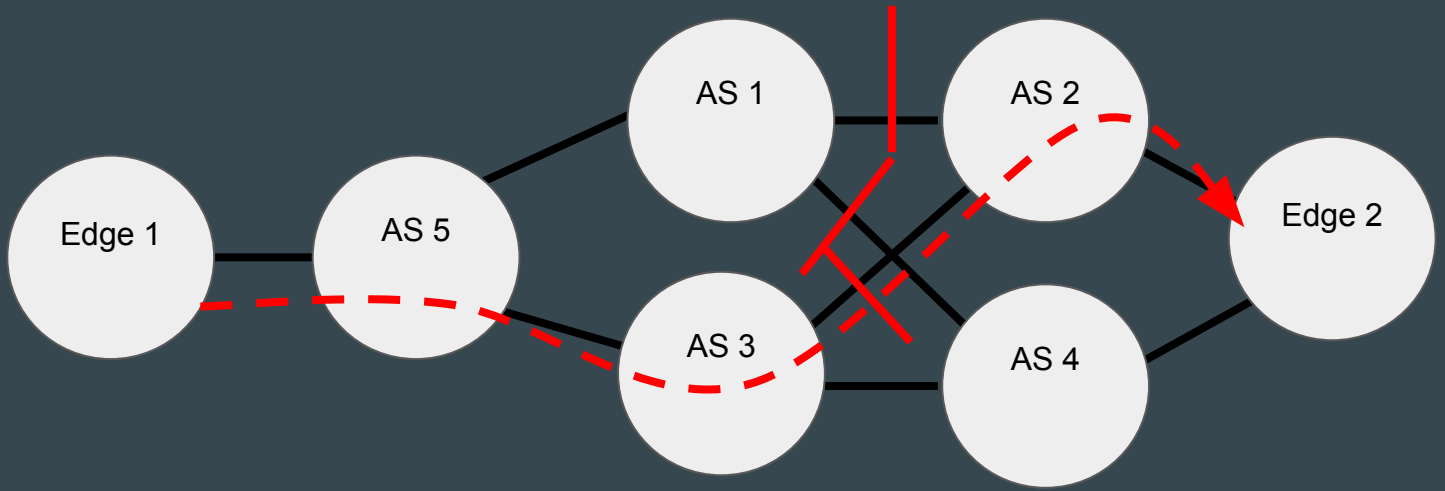
Solution: automatically exposing Path Diversity with BGP pathfinder

BGP announcement propagation

Repeat

prefix: abcd:1::/48

communities: AS1:No_Export_to_AS2, AS1:No_Export_to_AS4, AS3:No_Export_to_AS2



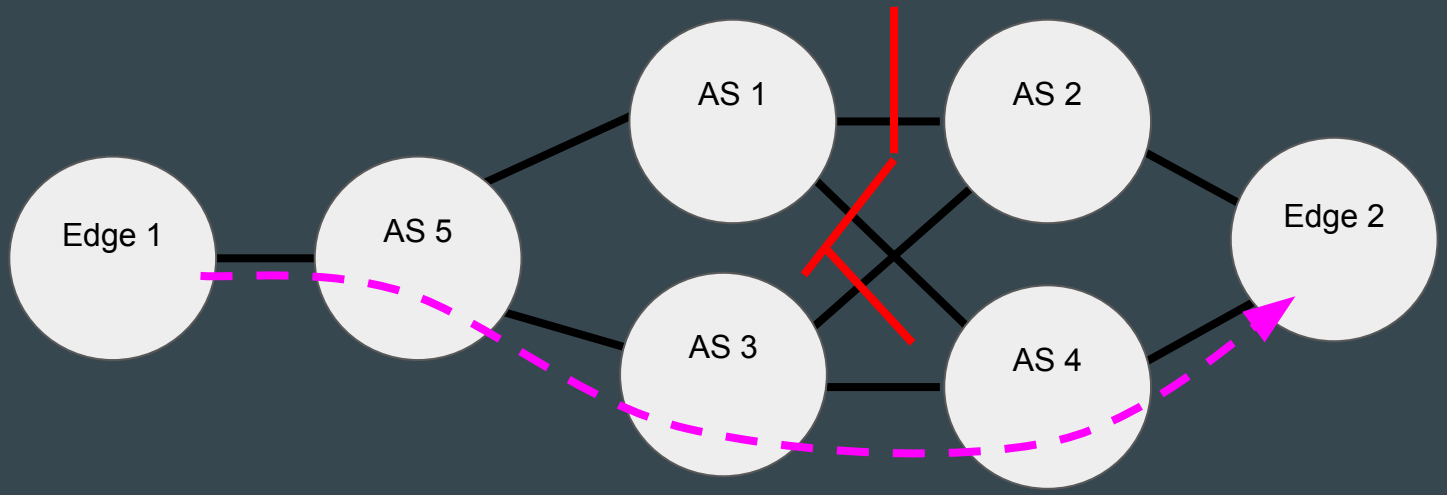
Solution: automatically exposing Path Diversity with BGP pathfinder

BGP announcement propagation

prefix: abcd:1::/48

communities: AS1:No_Export_to_AS2, AS1:No_Export_to_AS4, AS3:No_Export_to_AS2

Repeat...



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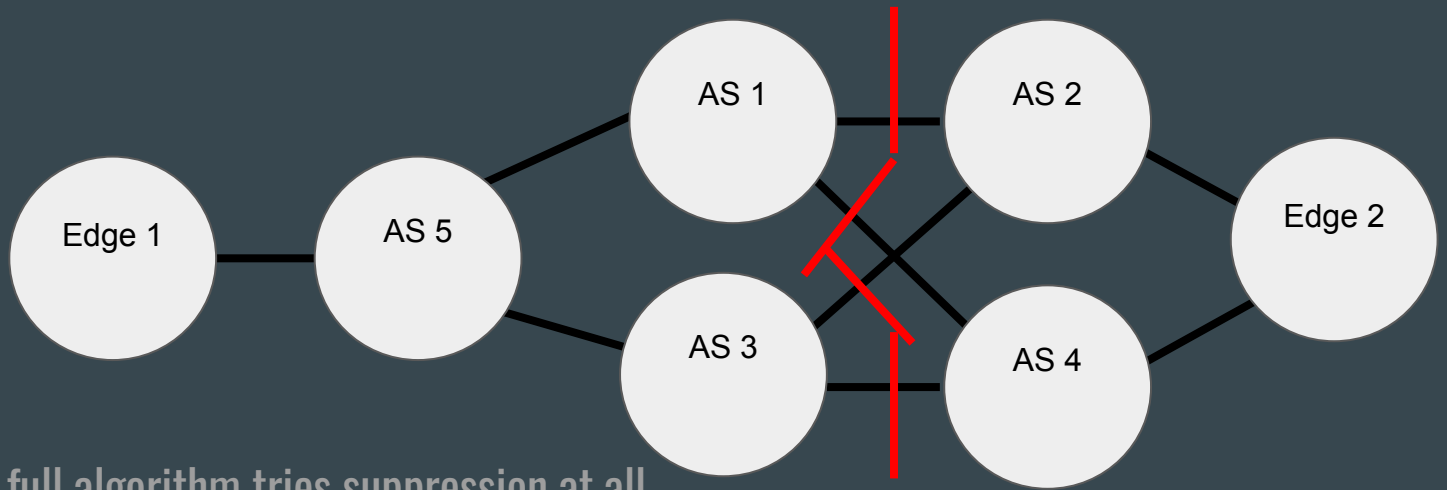
BGP announcement propagation

prefix: abcd:1::/48

communities: AS1:No_Export_to_AS2, AS1:No_Export_to_AS4, AS3:No_Export_to_AS2, AS3:No_Export_to_AS4

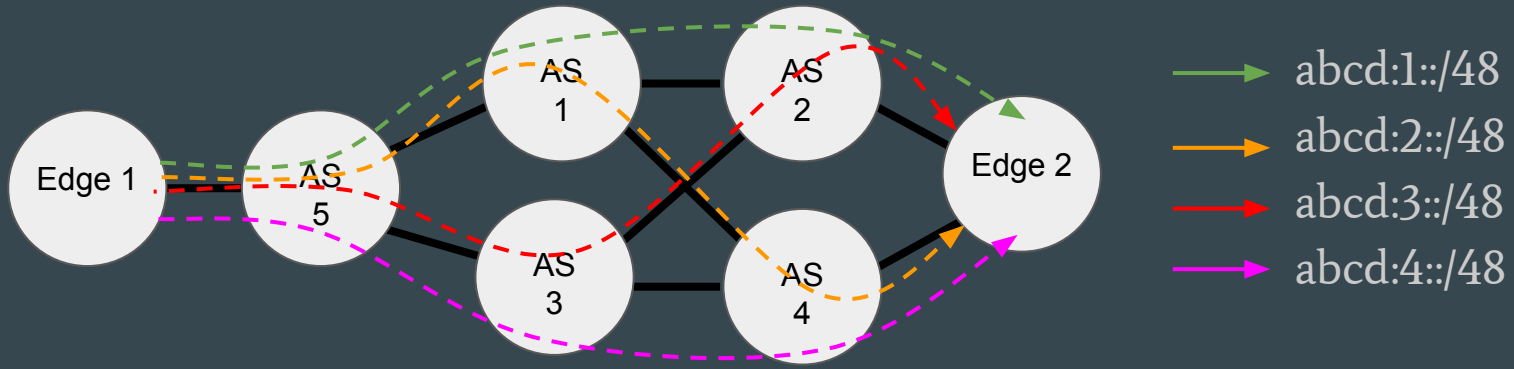
Stop when no paths remain



Note: full algorithm tries suppression at all hops along path

NO Paths Available

Different prefixes are announced along different paths

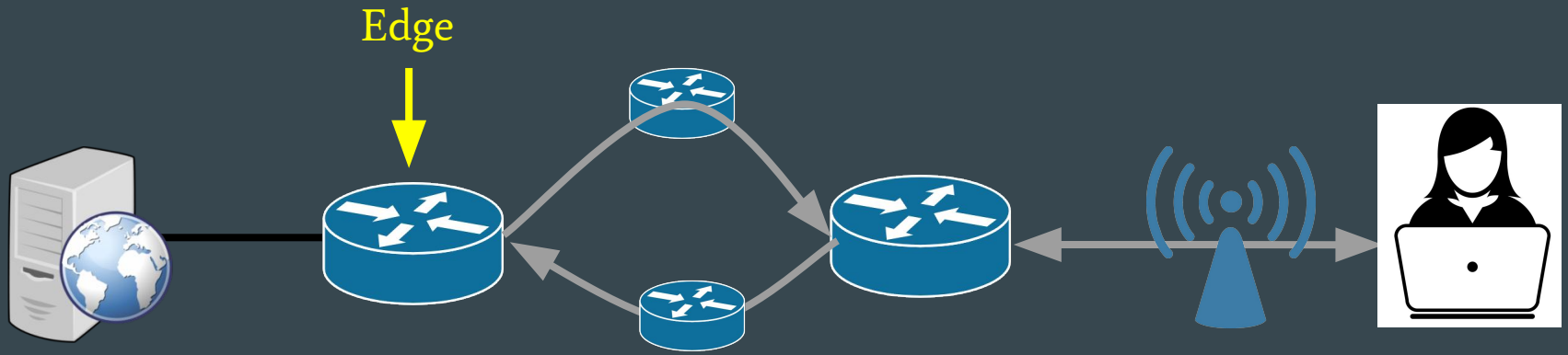


- ***Destination*** **Tango nodes** can announce multiple IP prefixes along different paths using BGP communities
- ***Source*** Tango node can select which path to use by selecting a prefix to reach the destination
- *BGP announcements* are stable, BGP pathfinder only needs to be rerun periodically

What would it take for the Internet to serve performance-critical apps?

- Path Diversity
- **Measurements** 
- Route Control

Why Measurements are hard



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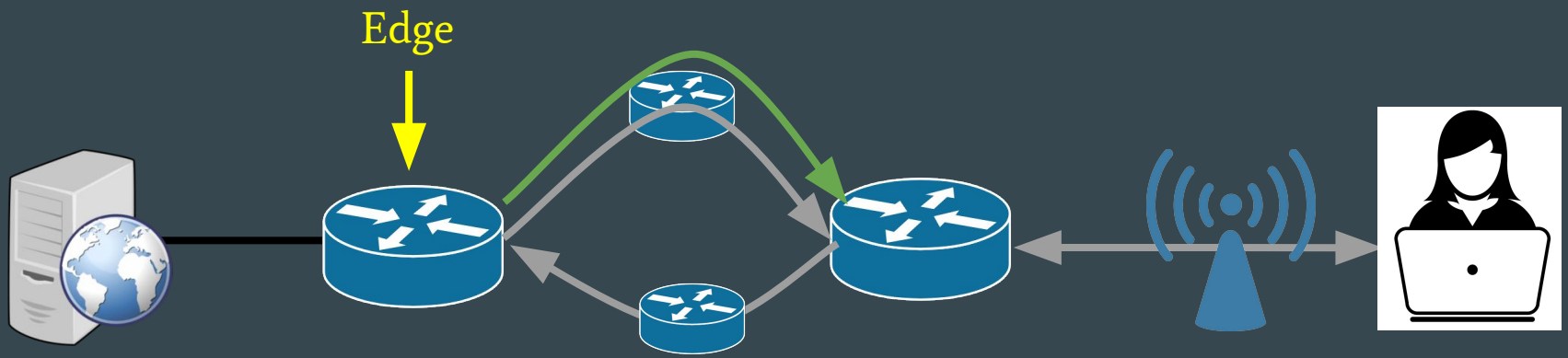

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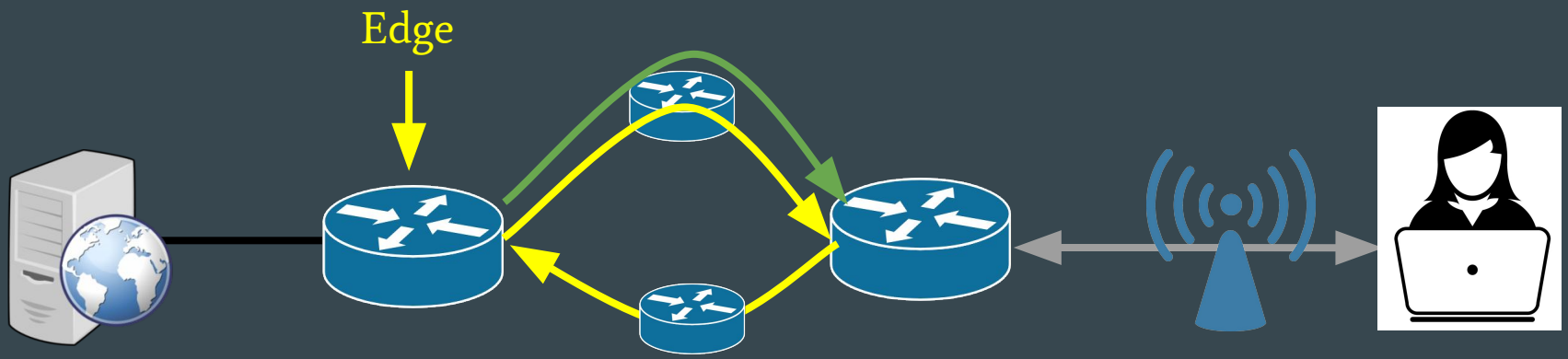

- An edge network only sees round-trip-time (RTT) not one-way-delay

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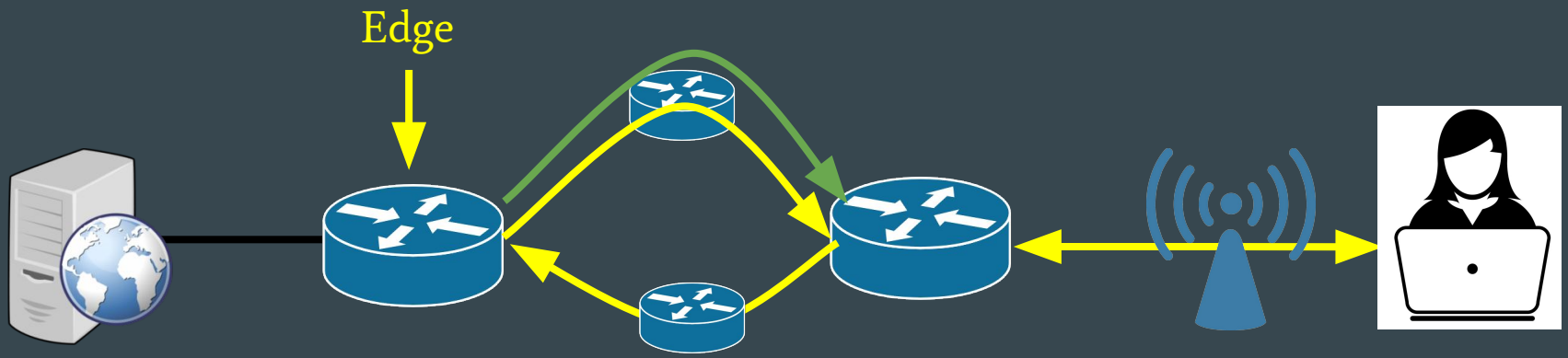

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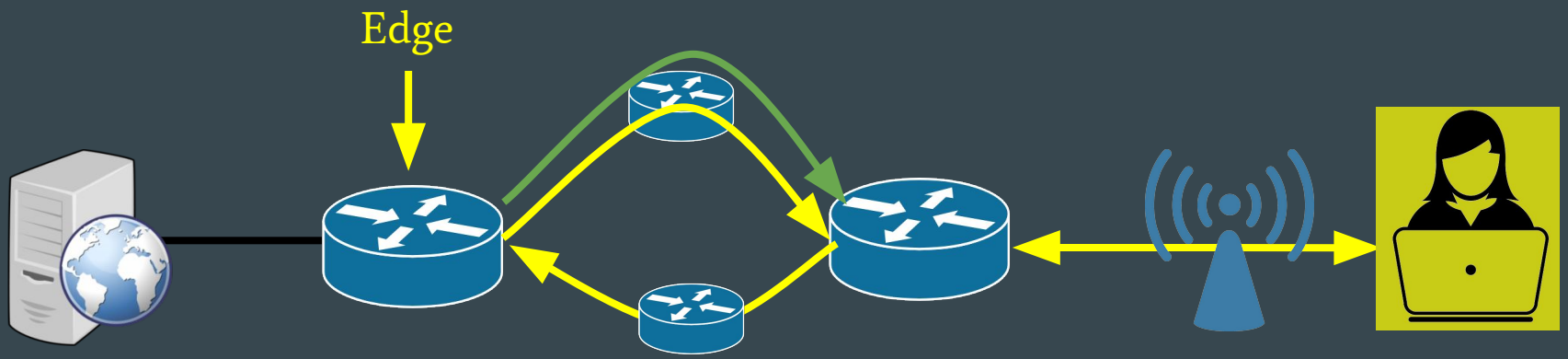

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- RTT monitoring requires understanding end host and L4 protocol behavior

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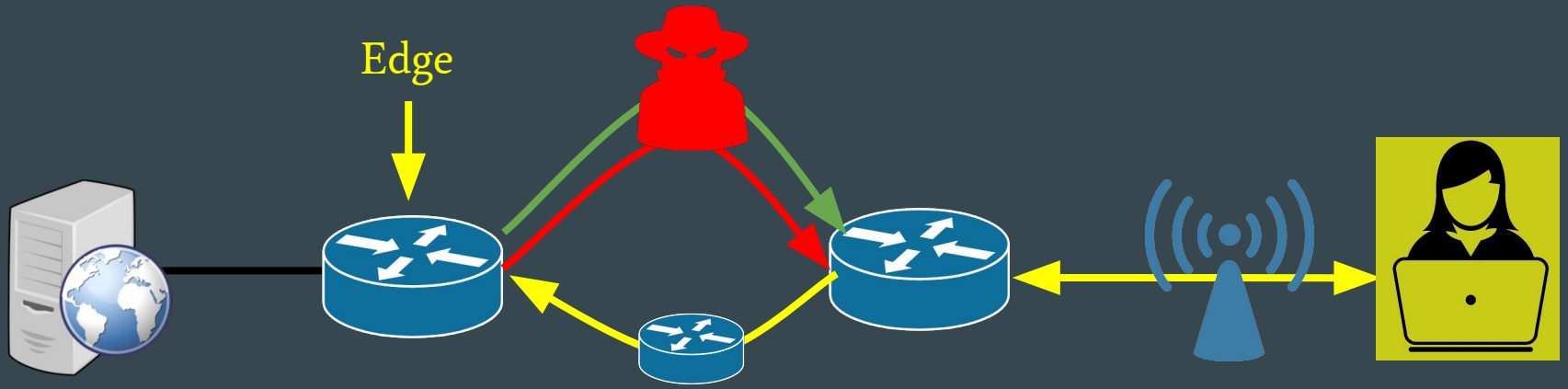

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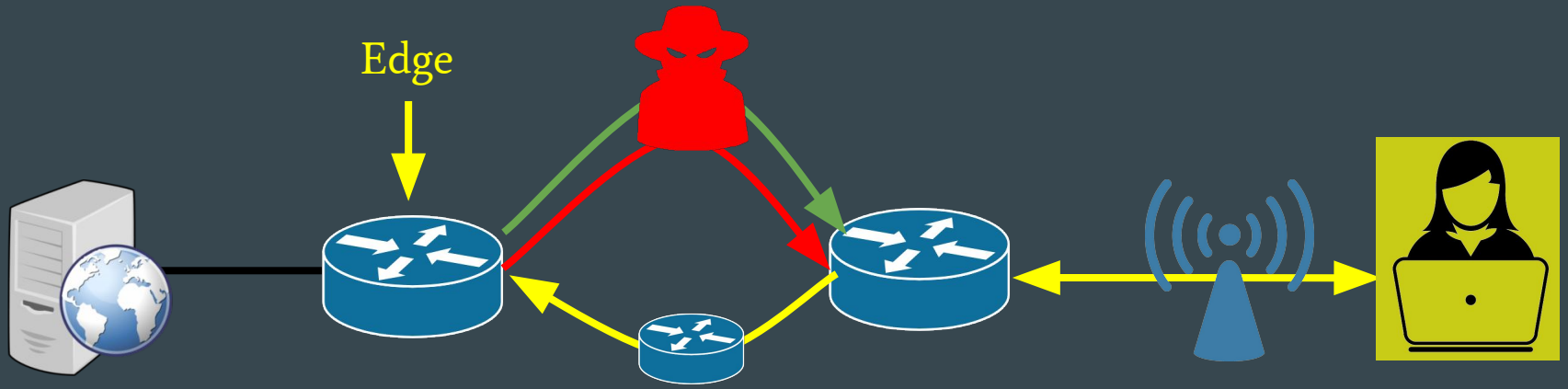
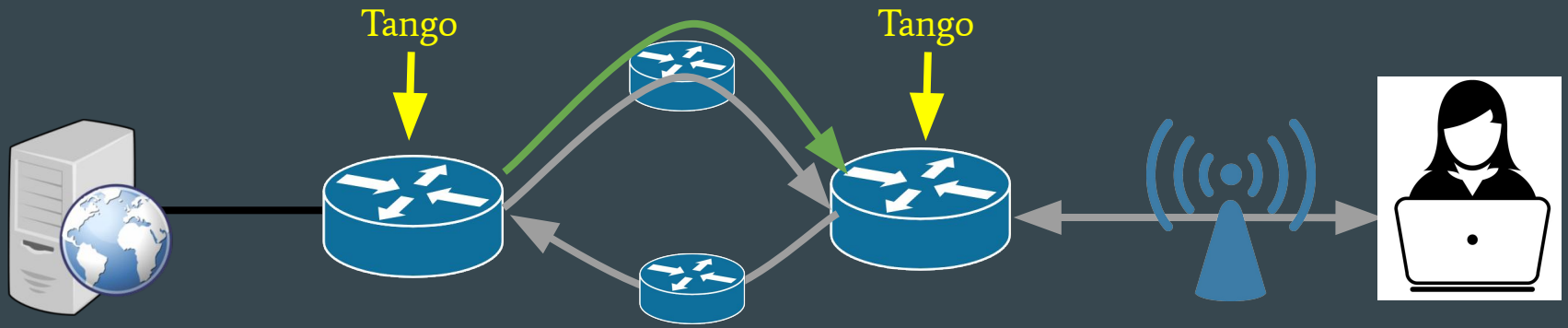


- An edge network only sees round-trip-time (RTT) not one-way-delay
- RTT includes edge network delays
- RTT monitoring requires understanding end host and L4 protocol behavior
- An attacker might try to persuade us that her RTT is lower
- Has to run at line rate

Improved Measurements through cooperation

- Custom Tango header added at the edge of the network using programmable switches or eBPF
- Measurements only include one-way, wide-area component
- Measurements do not rely on application behavior



Protecting measurements from adversaries

- An adversary could manipulate measurements to hijack traffic by making her route look more preferable

How to protect billions of sequence numbers a second?

- Protected packet fields:
  - Sequence numbers: protects against adversary hiding lost packets
  - Timestamps: protects against adversary manipulating latency
  - Route control messages: protects against adversary forging ctrl messages

Signing sequence numbers

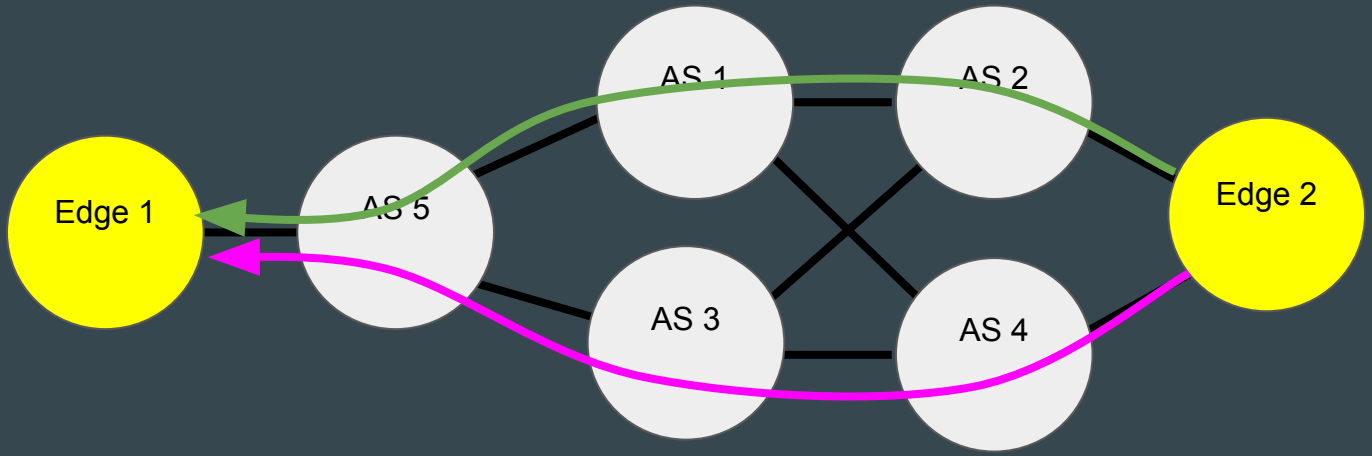
- Each sequence number **corresponds to an index** in a cipher book shared by the sender and receiver
- Packets contain the sequence number and **a single bit "signature"** from the corresponding book index to keep up with throughput
- Adversary has a 50/50 chance of guessing a signature, but **needs to guess many signatures** to meaningfully affect loss
- **Likelihood of avoiding detection** **decreases exponentially** with each guess

What would it take for the Internet to serve performance-critical apps?

- Path Diversity
- Measurements
- **Route Control** 

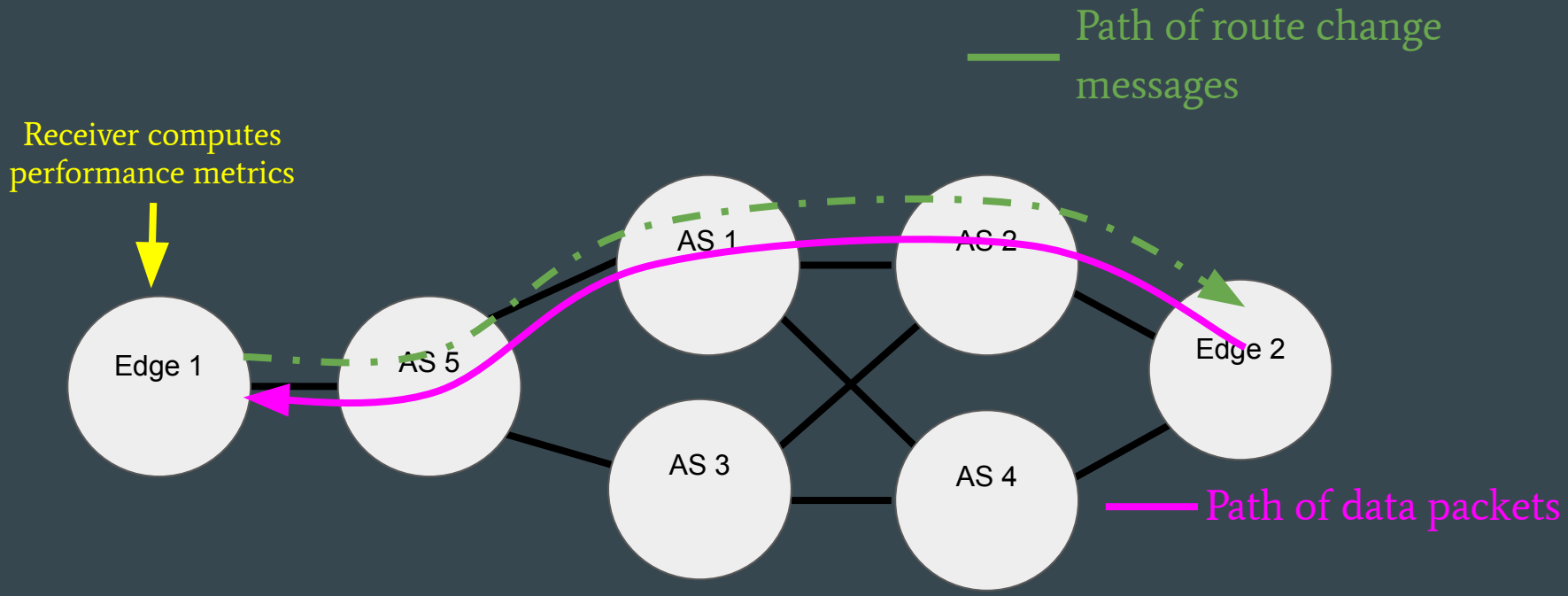
Challenges With Route Control

Consider traffic from Edge 2 to Edge 1



- Edge 1 sees one-way-delay data
- Edge 2 needs to know how to route packets

Real-time route control with Tango

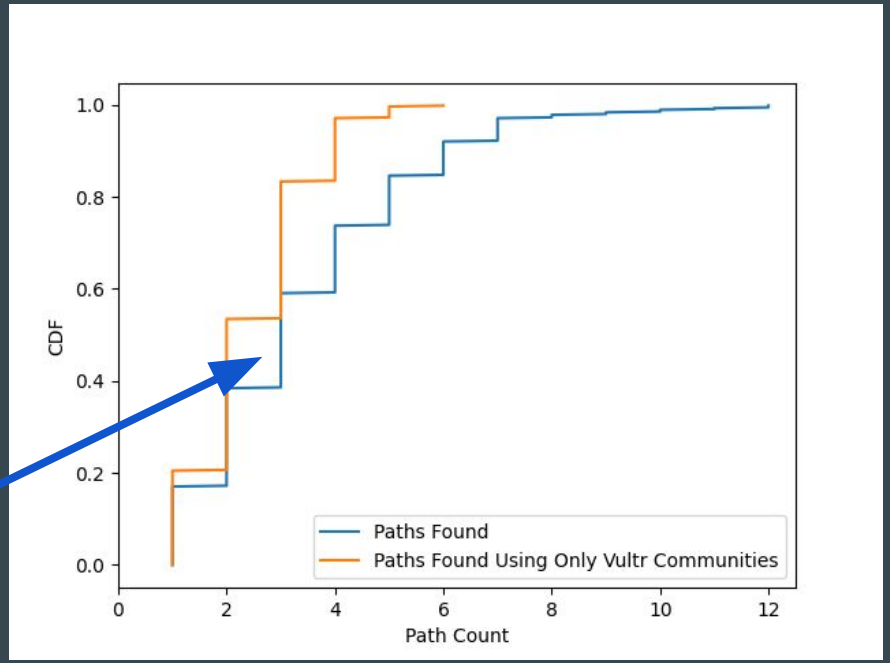


Evaluation

- **How many paths can we find?** 
- Can we beat the performance of the default path?
- Can we run measurements and crypto at line rate?

How many paths can we find?

- Ran BGP pathfinder between 503 globally-distributed nodes from the cloud provider Vultr
- Took ~30min per pair (can be parallelized)
- By default Vultr only exported a single path
- 80% of nodes had additional paths
- **BGP Pathfinder can expose 3 paths for the median pair**
- Some nodes had as high as 10-12 paths



Evaluation

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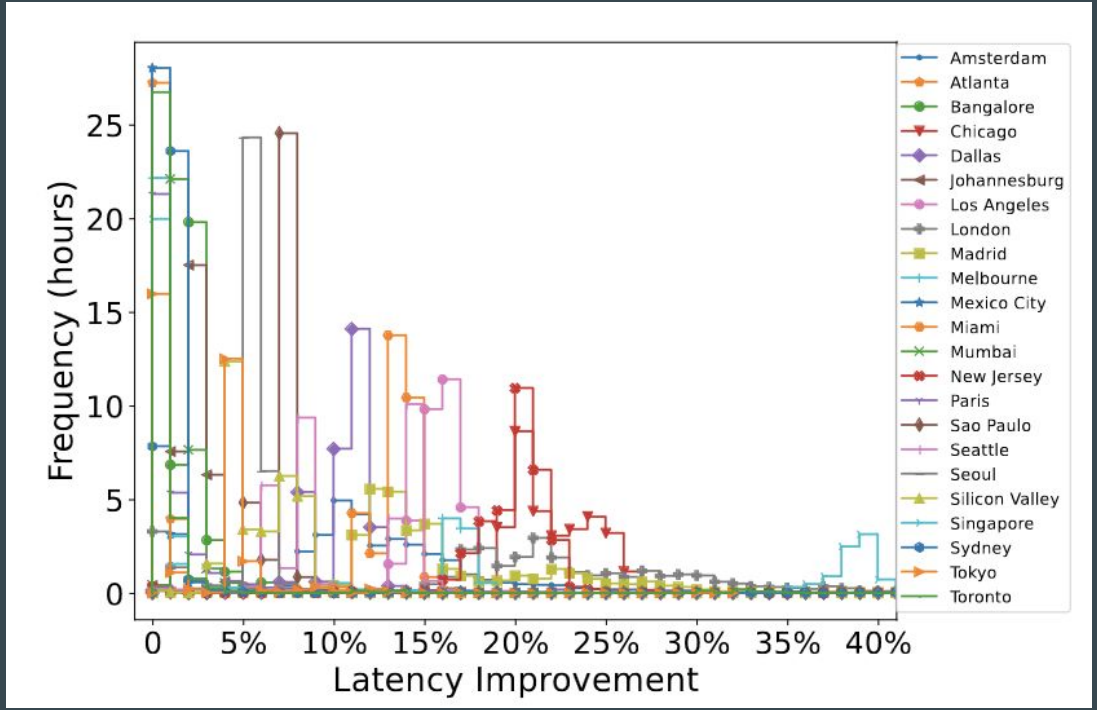
Tango performance measurements

- Took measurements from 25 global nodes
- Routed traffic over different paths to two destinations: LA and Stockholm
- Took latency and loss measurement every 10ms

Outperforming the Default Path

- For many src,dst pairs, the optimal Tango path had 22% lower latency than BGP default path
- In some cases, Tango saw a 39% improvement



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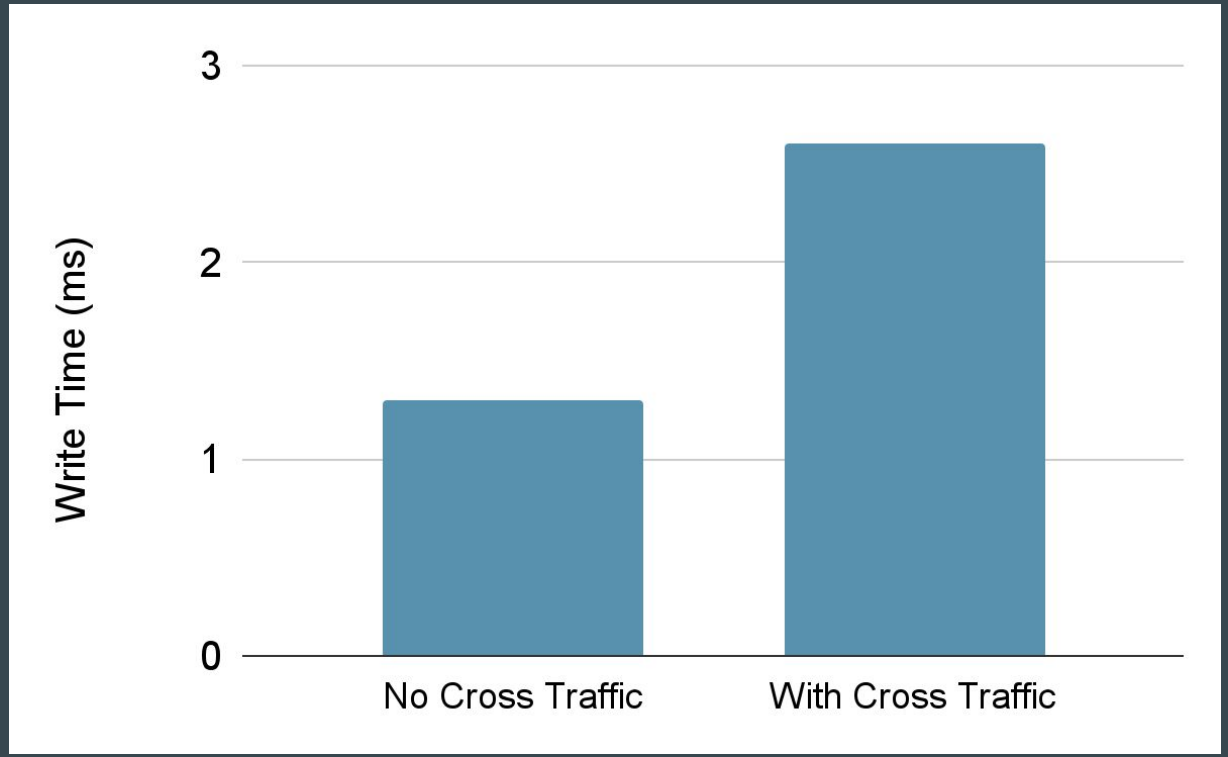
- **Can we run measurements and crypto at line rate?** 

Generating sequence number signatures at line rate

- Implemented on Tofino1 Programmable Switch
- Signature values sent to switch in dataplane
- Switch recirculated packets and wrote signatures to data-plane registers
- Wrote 2^{20} signatures in 2.6ms even with cross traffic
- Keeps up with 100Gbps line rate



Conclusion

Tango

3 surprising finds from Tango

- We can find alternative paths through the public Internet
- These paths often have improved performance
- We can run trustworthy telemetry in the data plane

Questions?

Thank you for your time

Henry Birge-Lee

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Offering Dynamic Route Control

- Several high-loss and high-latency events plague networks periodically
- Dynamically-switching to better paths can evade these events
- Often other unaffected paths exist