

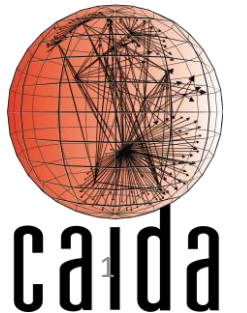
Mind Your MANRS:

Measuring the MANRS Ecosystem

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UC San Diego *MIT/Georgia Tech #IIJ Research Lab ^Stanford
ACM Internet Measurement Conference
Oct 27, 2022

UC San Diego



The MANRS Initiative

- The Mutually Agreed Norms on Routing Security initiative was launched by network operators in 2014.
- “MANRS provides crucial fixes to reduce the most common routing threats¹”. -- About MANRS



MANRS

1. <https://www.manrs.org/about/>

Internet routing vulnerability

- The Border Gateway Protocol includes no mechanism to validate information exchanged between networks.
- Attackers can advertise IP address space without authorization. (BGP Hijacking)

Crypto Exchange KLAYswap Loses \$1.9M After BGP Hijack

Hackers Performed Border Gateway Protocol Hack to Conduct Illegal Transactions

Prajeet Nair ([@prajeetspeaks](#)) • February 16, 2022

BORDER GATEWAY PROTOCOL INSECURITY —

How 3 hours of inaction from Amazon cost cryptocurrency holders \$235,000

For 2nd time in 4 years, Amazon loses control of its IP space in BGP hijacking.

DAN GOODIN - 9/23/2022, 11:04 AM

Infrastructure to improve routing security

- One way to address routing threats is to validate received BGP information.
 - Compare BGP information with external reference information
- **Routing databases** provide reference information.
 - BGP prefix origin classified as Valid, Invalid, and NotFound

- Internet Routing Registry (IRR)

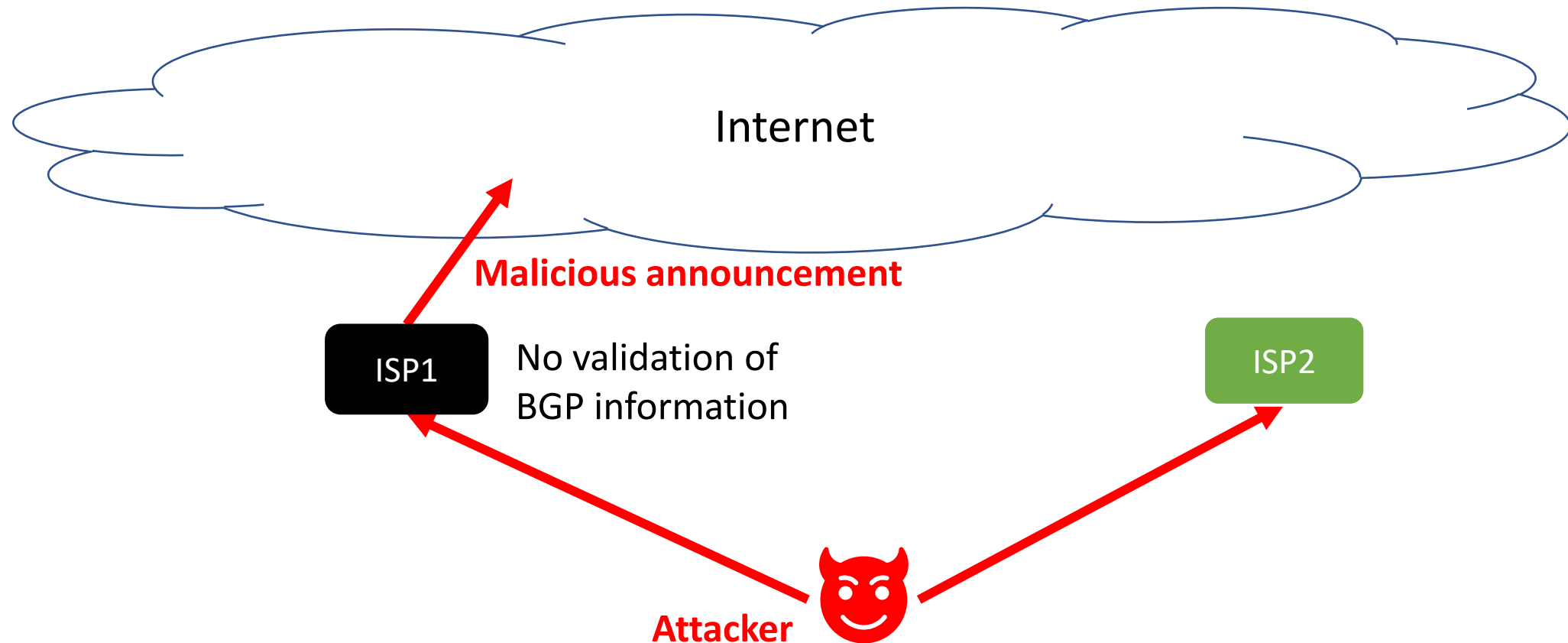


- Resource Public Key Infrastructure (RPKI)
 - 5 RIRs as root of trust



Routing security is a collective action problem

- Networks need to collectively adopt routing security practices to improve overall routing security



MANRS security practices

- Networks have misaligned incentive to implement security practices.
- MANRS encourages networks to adopt routing security practices.

- Register intended BGP announcements in IRR or RPKI.
- Use IRR/RPKI to check correctness of customers' BGP announcements.

- Do MANRS participants implement the security practices they committed to?

Is MANRS a useful approach?

Analyze the MANRS Ecosystem as a third party

1. How has MANRS participation grown over the past 6 years?

Participation

2. Are MANRS networks properly implementing MANRS practices?

Conformance

3. Are MANRS networks more likely to filter RPKI Invalid announcements?

Impact

Research Questions & Datasets

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MANRS participants list

CAIDA IPv4 Prefix2AS

Internet Health Report

Research Questions & Datasets

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Internet Health Report

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MANRS participants list

CAIDA IPv4/IPv6 Prefix2AS

Internet Health Report

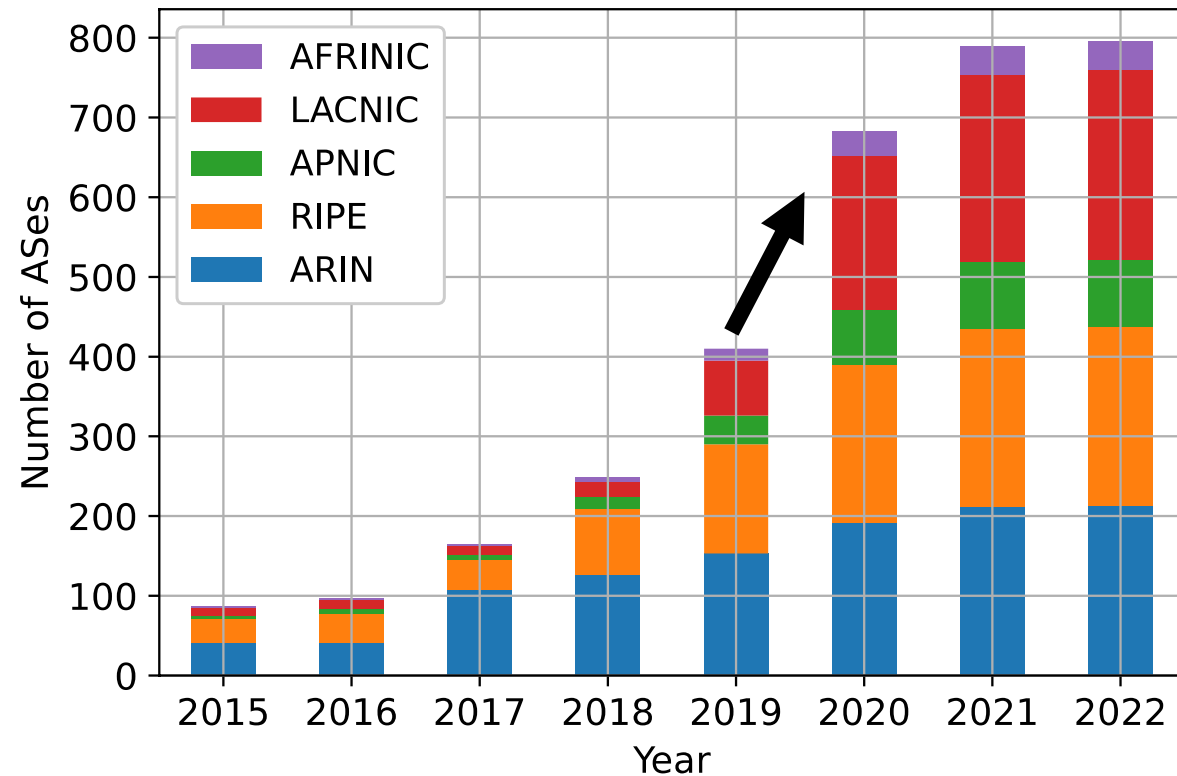
Outline

1. How has MANRS participation grown over the past 6 years?
2. Are MANRS networks properly implementing MANRS practices?
3. Are MANRS networks less likely to filter RPKI Invalid announcements?

MANRS participation has increased over the past 6 years

- MANRS has seen participation growth in different metrics
 - 732 ASes has joined MANRS between 2015 and May 2022
 - 11.4% of routed IPv4 address space were announced by new MANRS ASes.

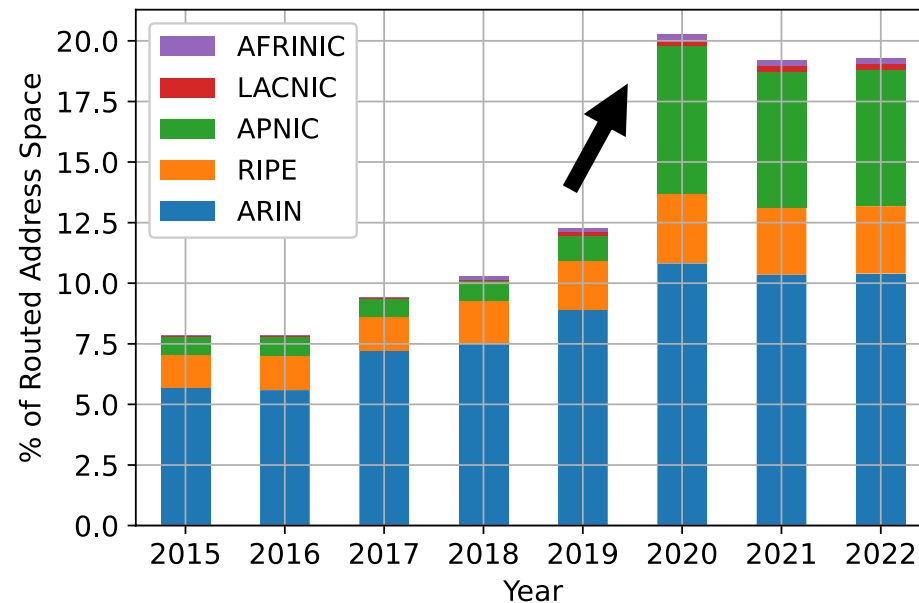
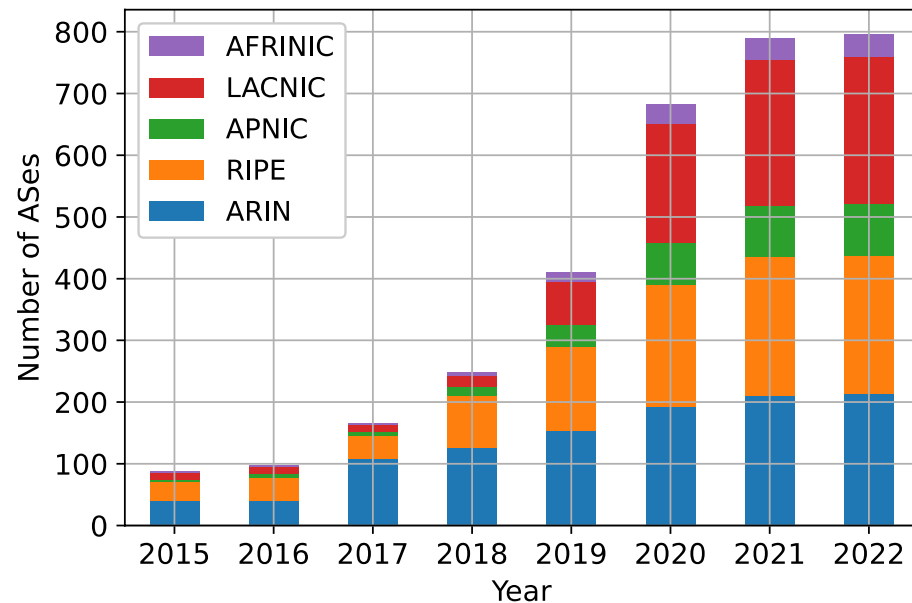
LACNIC has the most MANRS ASes



- Jump in LACNIC (Latin America) ASes between 2019 and 2020
- As of 2020, 184 ASes were registered in Brazil
 - Outreach effort by Brazilian Network Information Center

LACNIC ASes announce little address space

- China Telecom joined MANRS in 2020
 - 4% of routed v4 address space
- Amazon and Lumen in the ARIN (North America) region represented the most address space

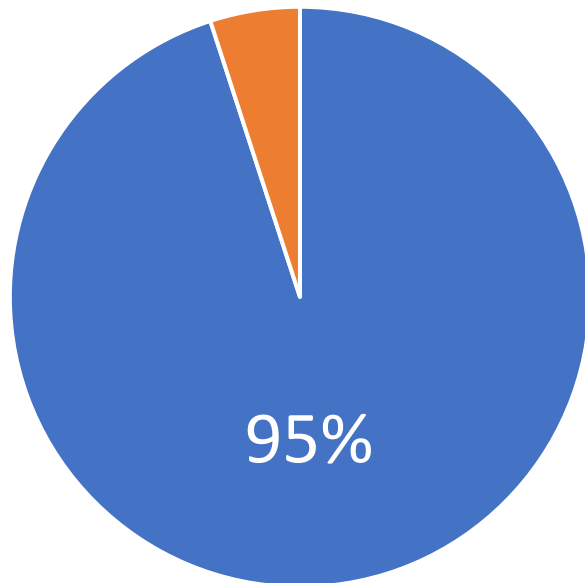


Outline

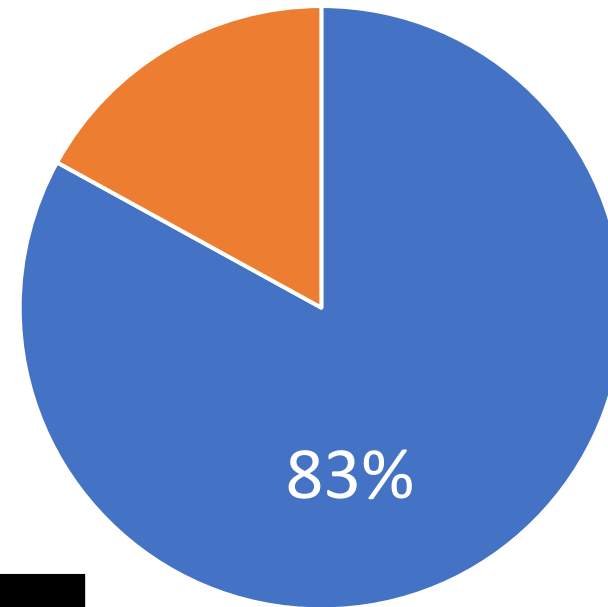
1. How has MANRS participation grown over the past 6 years?
2. Are MANRS networks properly implementing MANRS practices?
 - Networks that properly implemented MANRS practices are considered conformant
3. Are MANRS networks less likely to filter RPKI Invalid announcements?

Most MANRS ASes are conformant

Register intended BGP announcements



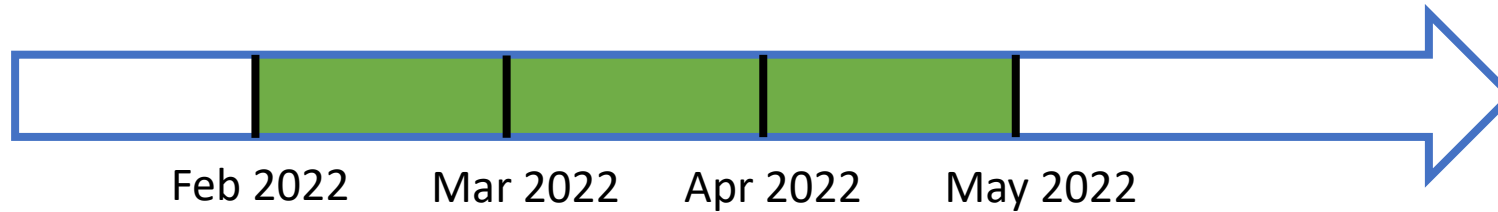
Filter incorrect customer announcements



■ Conformant
■ Non-conformant

May 1st 2022

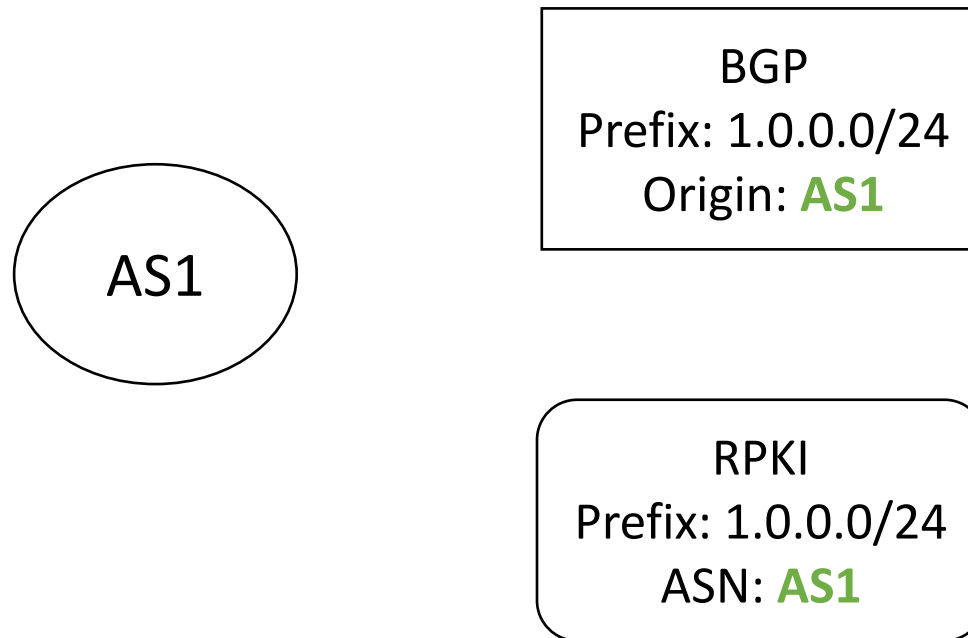
Most MANRS ASes stayed conformant



- Between February 2022 and May 2022, 94% of MANRS ASes stayed conformant.
 - 803/849 in the MANRS Network Operators Program
 - 18/21 in the MANRS CDN program
- Keeping RPKI/IRR records up to date is important for facilitating BGP information validation.
- MANRS networks are more likely to keep routing database records up to date than non-MANRS networks

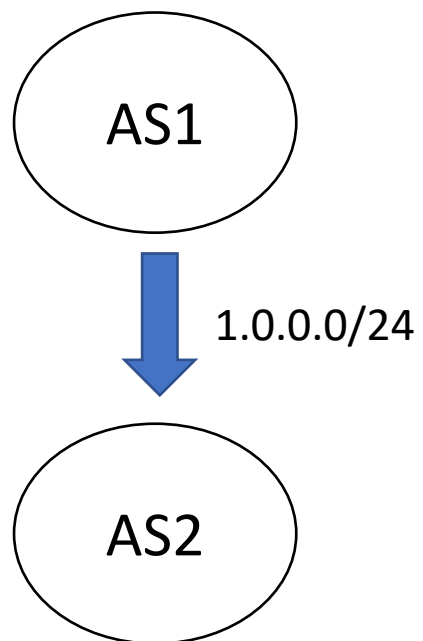
Complex AS relationships can complicate conformance

- Example: customer-provider relationships



Complex AS relationships can complicate conformance

- Example: customer-provider relationships
- AS1 gains a new customer AS2 and assigns 1.0.0.0/24 to AS2



BGP
Prefix: 1.0.0.0/24
Origin: **AS2**

RPKI
Prefix: 1.0.0.0/24
ASN: **AS1**

Mismatch!
AS2 not conformant

Complex AS relationships can complicate conformance

- Manually analyzed 6 non-conformant ASes
 - 3 large transit providers
 - 3 CDNs/Cloud providers
- 50% of prefixes whose BGP origin AS did not match RPKI/IRR registration had related ASes
 - likely to be operational oversight.
- Such mismatches are likely not malicious but can cause service disruptions.

Outline

1. How has MANRS grown over the past 6 years?
2. Are MANRS networks properly implementing MANRS practices?
3. Are MANRS networks more likely than non-MANRS networks to filter RPKI Invalid announcements?

Outline

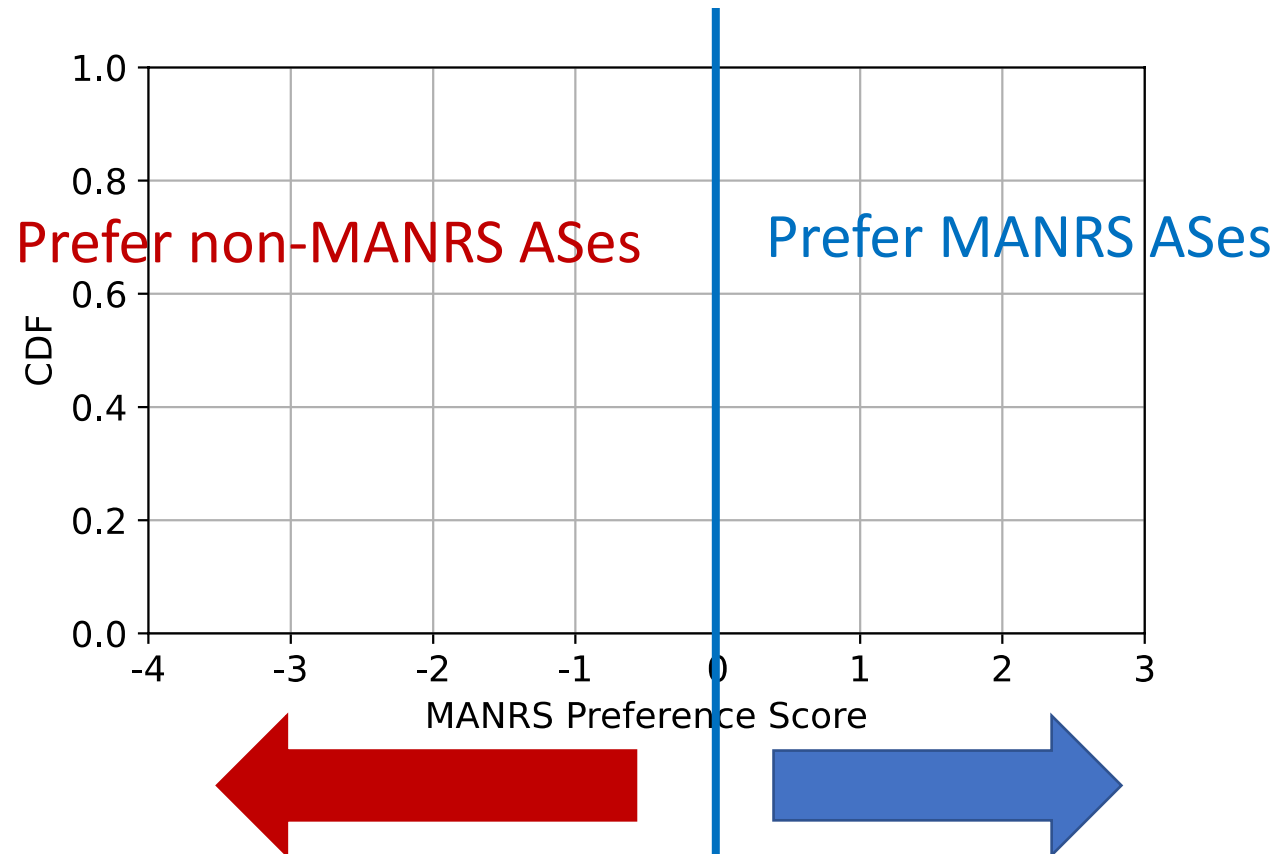
1. How has MANRS grown over the past 6 years?
2. Are MANRS networks properly implementing MANRS actions?
- 3. ~~Are MANRS networks more likely than non-MANRS networks to filter RPKI Invalid announcements?~~**

Outline

1. How has MANRS grown over the past 6 years?
2. Are MANRS networks properly implementing MANRS actions?
3. Are MANRS networks less likely than non-MANRS networks to propagate false BGP announcements?
 - We compare the prevalence of MANRS ASes and non-MANRS ASes in the AS-PATH of RPKI Invalid prefixes.

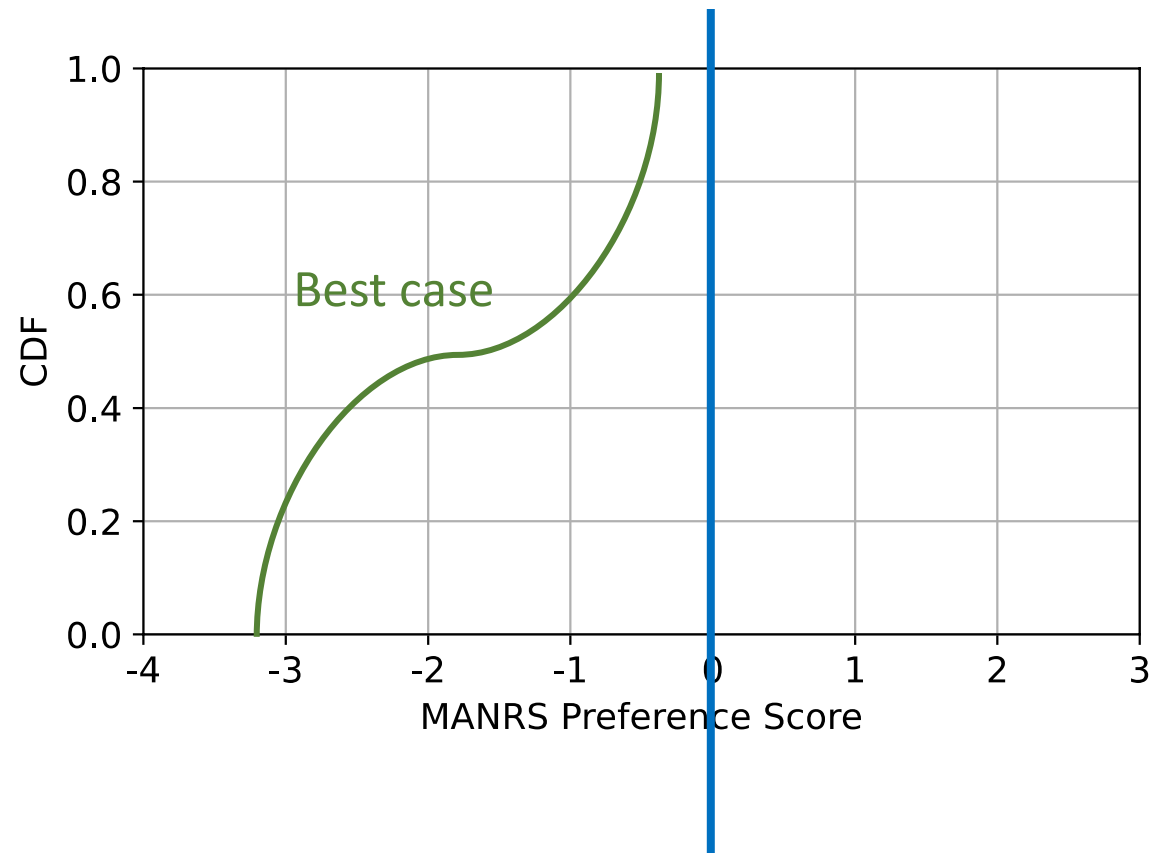
MANRS Preference Score

- We define an RPKI Invalid prefix to “prefer” MANRS ASes if we observe more MANRS than non-MANRS ASes in its upstream AS-PATHs.



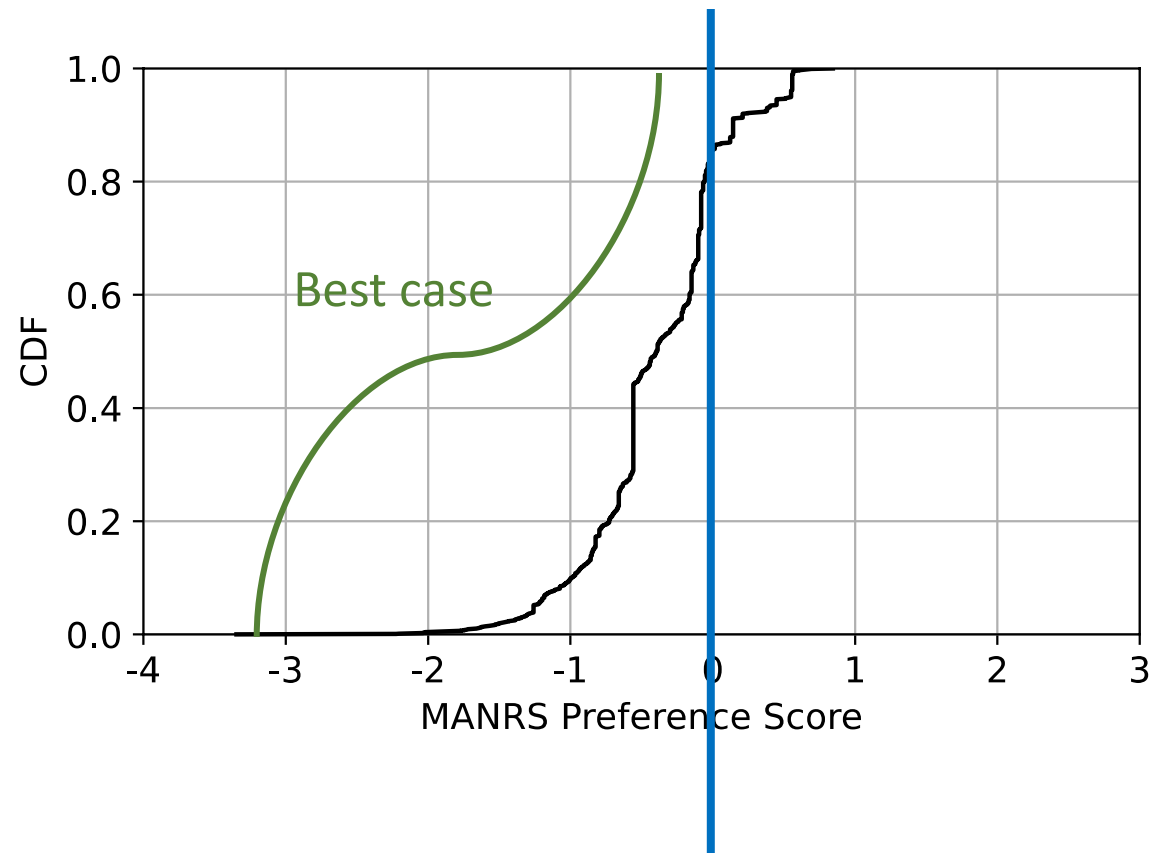
Best case: MANRS ASes filter out **all** RPKI Invalid prefixes

- All RPKI Invalid prefixes would prefer non-MANRS ASes.



MANRS ASes are more effective in RPKI filtering than non-MANRS ASes

- In May 2022, **14%** RPKI Invalid prefixes preferred MANRS ASes.



Conclusion

- We found MANRS participation has increased in the past 6 years.
 - Between 2015 and 2022, MANRS gained 732 ASes that announced 11.4% of the routed IPv4 address space.
- 83% MANRS networks are conformant to MANRS practices.
 - But some large networks did not register in IRR/RPKI.
- 14% RPKI Invalid announcements preferred MANRS ASes.
 - MANRS networks are more effective than non-MANRS networks in filtering RPKI Invalid BGP announcements.



Questions?

- Email me: bendu@ucsd.edu
- Thanks to my collaborators and advisors: Cecilia Testart, Romain Fontugne, Gautam Akiwate, Alex C. Snoeren, kc claffy.

