#### **RPKI: Latest Research and Operational Insights in Japan**

- Romain Fontugne (IIJ): Overview of RPKI research at IIJ.
- Keisuke Ishibashi (ICU): Social Dilemma in the Adoption of RPKI and its Possible Resolution through Altruism and Bounded Rationality.
- Wataru Ohgai (JPNIC): What matters to your life? from RPKI point of view.

# **Overview of RPKI research at IIJ**

# Romain Fontugne

iijlab seminar 2025/04/15

**Ongoing Innovation** 



• BGP route propagation is based on trust



BGP route propagation is <u>based on trust</u>



- BGP route propagation is based on trust
- RPKI uses digital certificate to add cryptographic validation



- BGP route propagation is based on trust
- RPKI uses digital certificate to add cryptographic validation



# **RPKI research at IIJ**

#### **Objectives**

- Explore and understand the RPKI ecosystem
  - **Deployment:** How fast is the deployment of RPKI? Who is using RPKI?
  - **Impact:** How RPKI impacts the Internet? Operations?
- Make recommendations to RIR, software developers, and operators

#### **IHR RPKI Dashboard**

 Which prefixes are in RPKI? Invalid? How they propagate? IHR website (<u>https://www.ihr.live/en/rov</u>)

Enter an AS ID	IXP, network name	, prefix or country	Q			Home	Reports 🔻	Tools	➡ Documentation	API C	
S Route Origin Validation											
3-day report ending on April 14, 2025 苗											
RPKI invalid											
	ROUTES		ORIGIN ASES			MAIN TRANSITS			API		
Q Search											
		Route				AS dependency ③					
Country	Origin ASN	Prefix		RPKI	IRR	Prefix	Origin ASN	Visibility 🗸	Main Transits		
BD	AS137453	103.7.123.0/24JH GLOBAL TECHNOLOGY LTD 385, AL	odul Halim Mansion, Chawk Bazar,	× Invalid	🗸 Valid	✓ assigned	✓ assigned	72.6%	AS6939, AS9498, AS150178,	AS6762, AS57463	
US	AS393336	176.46.153.0/24		× Invalid	× Invalid	✓ assigned	✓ assigned	70.2%	<b>AS29802, AS6939</b> , AS3257		
US	AS393336	176.46.154.0/24	autogen	× Invalid	× Invalid	✓ assigned	✓ assigned	70.2%	<b>AS29802, AS6939</b> , AS3257		
US	AS53356	200.229.16.0/24		× Invalid	? NotFound	✓ assigned	✓ assigned	67.9%	AS6939		
sc	AS49581	2a12:d540::/29		× Invalid	× Invalid	✓ assigned	✓ assigned	66.3%	AS6939		
UA	AS209242	45.94.169.0/24	PNAP-NYM dedipath	× Invalid	× Invalid	✓ assigned	✓ assigned	65.5%	AS13335		
US	AS213448	2a13:5040::/29		× Invalid	? NotFound	✓ assigned	✓ assigned	65.1%	AS49581, AS6939		
LT	AS6939	2a13:c3c0::/29		× Invalid	? NotFound	✓ assigned	✓ assigned	63.9%			
US	AS396982	45.45.253.0/24		× Invalid	? NotFound	✓ assigned	✓ assigned	63.1%	AS15169		
РК	AS60721	113.203.233.0/24 Orient Exp	press LDI Limited 14 N F-8 Markaz	× Invalid	× Invalid	✓ assigned	✓ assigned	61.9%	AS44901, AS38193, AS43260	, AS6762, AS9121	

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#### IHR RPKI Dashboard (<u>https://www.ihr.live</u>)

- Global, Country, and AS views
- Updated daily
- Data available via API / downloads

#### Prefixes originated by IIJ

						Route Origin BGP / IRR / RPKI	n Validation / delegated									
Invalid Prefixes in Japan										Originated	prefix	•				
Route Origin V BGP / IRR / RPKI / d	alidation							ROUTES		ORIGIN ASES			MAIN	TRANSITS		API
		RPKI invalid	*				Q Search									
ROUTES ORIGIN ASES MAIN TRANSITS							Route				Status (	?		AS depender		
Q Search							Country	Origin ASN	Prefix		<b>R</b> РКІ ↓	IRR	Prefix	Origin ASN	Visibility	Main Transits
	Route Status 💿		JP	AS2497	2001:300::/32	IIJ IPv6 BLOCK (AS2497)	🗸 Valid	🗸 Valid	? NotFound	✓ assigned	100.0%	AS6939, AS2914, AS174, A				
Origin ASN	Prefix	RPKI	IRR	Prefix	Origin ASN	Visibility $\downarrow$	JP	AS2497	2001:240::/32	IIJ IPv6 BLOCK (AS2497)	🗸 Valid	🗸 Valid	? NotFound	✓ assigned	100.0%	AS6939, AS2914, AS174, A
AS209242	154.197.88.0/24 Beijingmiaoshutuoyufuwuyouxiangongsi	× Invalid	× Invalid	✓ assigned	assigned	60.7%	US	AS2497	2001:48b0::/32IIJ	America IPv6 BLOCK ( AS2497 )	🗸 Valid	🗸 Valid	✓ assigned	✓ assigned	100.0%	AS6939, AS2914, AS174, A
AS209242	154.197.80.0/24 SKYDIGITAL_TELECOM_LTD	× Invalid	× Invalid	assigned	✓ assigned	58.3%	JP	AS2497	210.148.0.0/16	IIJ IPv4 BLOCK (AS2497)	🗸 Valid	🗸 Valid	✓ assigned	✓ assigned	100.0%	AS1299, AS2914, AS3356,
AS13335	2a09:bac0:594::/48	× Invalid (more specific)	🗸 Valid	✓ assigned	✓ assigned	49.4%	JP	AS2497	58.138.0.0/17	IIJ IPv4 BLOCK (AS2497)	🗸 Valid	🗸 Valid	🗸 assigned	✓ assigned	100.0%	AS1299, AS2914, AS3356,
AS152858	2401:b720::/33 Woven by Tayota, Inc. IPv6 Address-blook NO.2-1	× Invalid (more specific)	<ul> <li>Valid</li> </ul>	✓ assigned	✓ assigned	32.5%	JP	AS2497	220.156.0.0/18	IIJ IPv4 BLOCK (AS2497)	🗸 Valid	🗸 Valid	✓ assigned	✓ assigned	100.0%	AS1299, AS2914, AS3356,
AS152858	2401:b720:8000::/33 Woven by Tayota, Inc. IPv6 Address-block NO.2-2	× Invalid (more specific)	<ul> <li>Valid</li> </ul>	✓ assigned	✓ assigned	32.5%	JP	AS2497	211.14.32.0/19	IIJ IPv4 BLOCK (AS2497)	🗸 Valid	🗸 Valid	✓ assigned	✓ assigned	100.0%	AS1299, AS2914, AS3356,
AS131971	2407:9900:1000::/36	× Invalid	? NotFound	∽ assigned	∽ assigned	31.3%	JP	AS2497	157.65.8.0/21	IIJ IPv4 BLOCK (AS2497)	🗸 Valid	Valid	✓ assigned	✓ assigned	100.0%	AS1299, AS2914, AS3356,
AS4637	61.14.139.0/24 Telstra International Limited 19/F Telecorn House 3 Gloucester Ro	× Invalid (more specific)	× Invalid (more specific)	∽ assigned	∽ assigned	29.8%	JP	AS2497	103.2.58.0/23	IIJ IPv4 BLOCK (AS2497)	🗸 Valid	🗸 Valid	✓ assigned	✓ assigned	100.0%	AS1299, AS2914, AS3356,
AS396417	2401:ce80:1001::/48	× Invalid	? NotFound	∽ assigned	∽ assigned	26.5%	JP	AS2497	202.32.0.0/16	IIJ IPv4 BLOCK (AS2497)	🗸 Valid	🗸 Valid	✓ assigned	✓ assigned	100.0%	AS1299, AS3356, AS2914
AS152858	209.107.142.0/23 Woven by Toyota, Inc. CIDR-block NO.2-2	× Invalid (more specific)	<ul> <li>Valid</li> </ul>	assigned	✓ assigned	26.2%								Rec	ords per page: 1	0 ▼ 1-10 of 180  <
AS152858	209.107.140.0/23 Woven by Toyota, Inc. CIDR-block NO.2-1	<ul> <li>Invalid (more specific)</li> </ul>	🗸 Valid	✓ assigned	✓ assigned	26.2%										

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# **Identifying Current Barriers in RPKI Adoption**

#### What drives the deployment of RPKI? Why NOT using RPKI?



#### (a) RPKI adoption by address space.



#### (b) RPKI adoption by networks

AS Rank	ASN	Org. Name	# Prefixes	Addr Size in $/24$	RPKI coverage $\%$
1	3356	Lumen	938	116,864	0.10
2	1299	Arelion	86	872	95.18
3	174	Cogent	4136	106,561	0.55
4	2914	$\operatorname{NTT}$	261	26,819	95.04
5	6762	Telecom Italia	161	412	46.12
6	6939	Hurican Electric	225	2236	68.83
7	3257	$\operatorname{GTT}$	913	26,146	11.23
8	6453	Tata	96	2242	86.89
9	6461	Zayo	198	6194	3.76
10	3491	PCCW Global	449	3951	97.37

Table 4: Characteristics of the 10 top ranked networks using RPKI

→ Good steady deployment until 50% but probably it's the easiest part
 I Testart et al. "Identifying Current Barriers in RPKI Adoption", TPRC'24

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#### **RoVista**

Who is implementing ROV?

- Measurement technique based on:
  - **IP-ID**
  - IP spoofing



# **RoVista: Results**

~3 years of results: <u>https://rovista.netsecurelab.org</u>
32k ASes

Search By ASN	▼ Search					
Rank	ASN	Country	Organization	ROV- Score	Last updated on	
1	ل∠ 3356	United States	Level 3 Parent, LLC	100.0%	2025-04-10	<ul> <li>Partially protected (&gt; 0)</li> <li> Fully protected (= 100)</li> </ul>
2	<b>소</b> 1299	Sweden	Arelion Sweden AB	100.0%	2025-04-10	
3	LZ 174	United States	Cogent Communications	100.0%	2025-04-10	
4	₩ 3257	United States	GTT Communications Inc.	100.0%	2025-04-10	
5	<u>₩</u> 2914	United States	NTT America, Inc.	100.0%	2025-04-10	
6	6939	United States	Hurricane Electric LLC	100.0%	2025-04-10	
7	<b>₩</b> 6453	United States	TATA COMMUNICATIONS (AMERICA) INC	100.0%	2025-04-10	
8	6762	Italy	Telecom Italia S.p.A.	0.0%	2025-04-10	0
9	6461	United States	Zayo Bandwidth	100.0%	2025-04-10	-222416-32216-092216-0016-0016-10216-09281-11-16-22216-0016-31-446-600816-12816-0014-010-120316-12916-0014
10	<u></u> 3491	United States	PCCW Global, Inc.	100.0%	2025-04-10	r ng rus na
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#### $\rightarrow$ Difficult to measure, still in early deployment stage(?)

■ Li et al. RoVista: "Measuring and Analyzing the Route Origin Validation (ROV) in RPKI"

## **RPKI** time-of-flight

#### • Is RPKI slow? Does it bother BGP operations/automation?



# **RPKI time-of-flight (Cont.)**

#### • ROA creation, median delay in minutes:

	Sign*	NotBefore*	Publication <sup>†</sup>	Relying Party <sup>†</sup>	$BGP\ddagger$
AFRINIC	0 (0)	0 (0)	3(2)	14(13)	15~(16)
APNIC	10(13)	10 (13)	14 (16)	34 (38)	26~(28)
ARIN	- (-)	- (-)	69  (97)	81  (109)	95(143)
LACNIC	0 (0)	- (-)	54(32)	66~(42)	51 (34)
RIPE	0 (0)	0 (0)	4(4)	$14\ (13)$	18(18)
After fix:					
ARIN	- (-)	- (-)	8(9)	21 (22)	28(23)

 $\rightarrow$  Good understanding of BGP reactivity to RPKI changes

 $\rightarrow$  ARIN, APNIC, RIPE updated their software based on this study

Fontugne et al. "RPKI Time-of-Flight: Tracking Delays in the Management, Control, and Data Planes", PAM'23

# **Relying Party delay**

#### **RP delay**

- 1. Fetch data from **all** publication points
- 2. Validate data
- 3. Push new data to routers



### Relying Party synchronization delay (cont.)



Maximum Depth of Certificate Chain

→ ARIN Delegated PP: double delay for only 7% more VRPs
 → Bundling speed up processing (APNIC & RIPE)

#### **Ongoing work**

#### Barriers in RPKI adoption

- How much adoption do we need?
- How hard would it be to get to max adoption?

#### Optimal ROV deployment

- Deploying ROV everywhere is not needed
- But where is the most effective places to deploy ROV?

# **Questions?**

## **Identifying Current Barriers in RPKI Adoption**



Testart et al. "Identifying Current Barriers in RPKI Adoption", TPRC'24