

Suppressing BGP Zombies with Route Status Transparency

Yosef Edery Anahory¹, Justin Furuness², Jie Kong², Nicholas Scaglione²,
Hemi Leibowitz³, Amir Herzberg², Bing Wang², Yossi Gilad¹

¹Hebrew University of Jerusalem

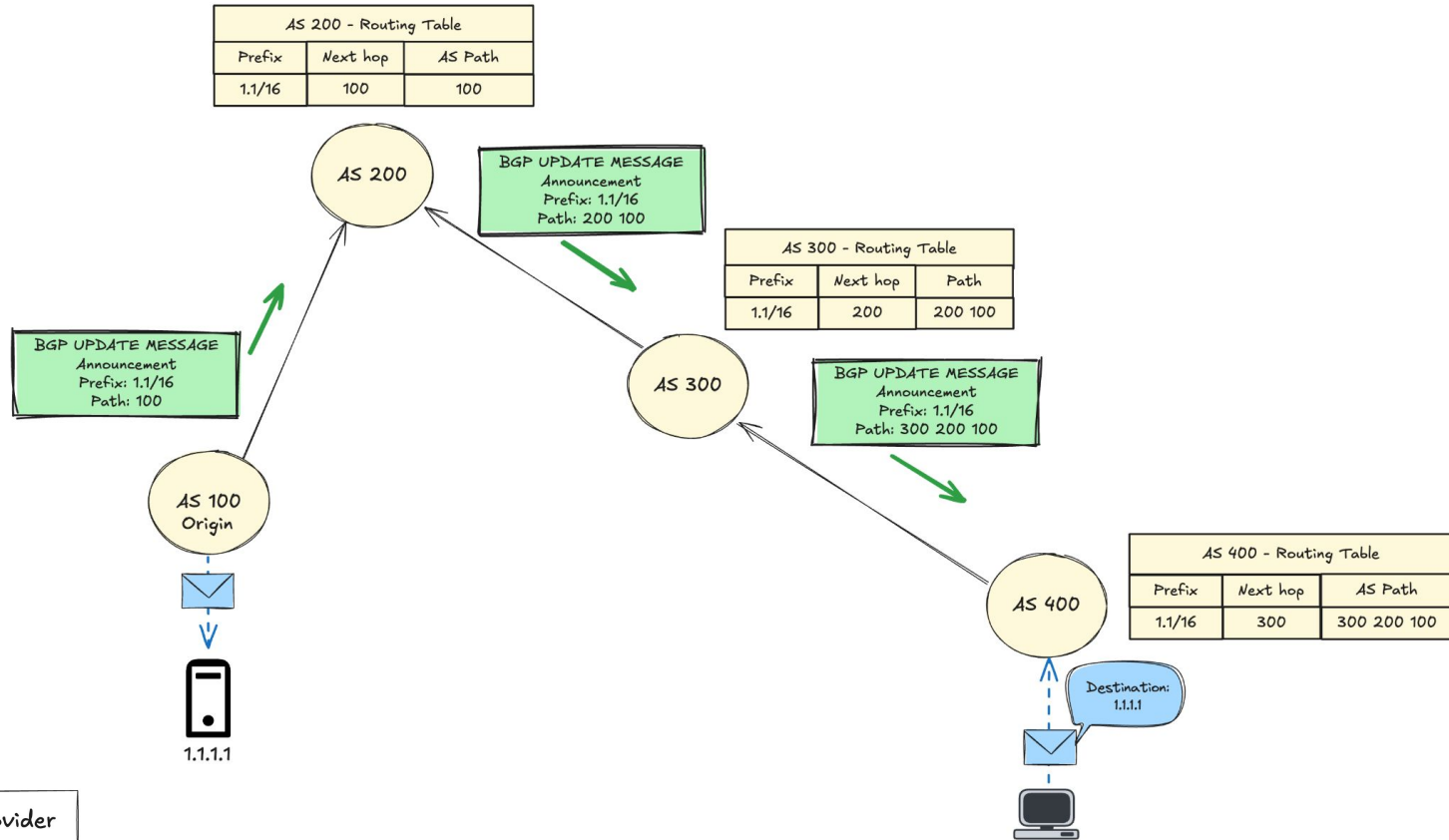
²University of Connecticut

³College of Management Academic Studies

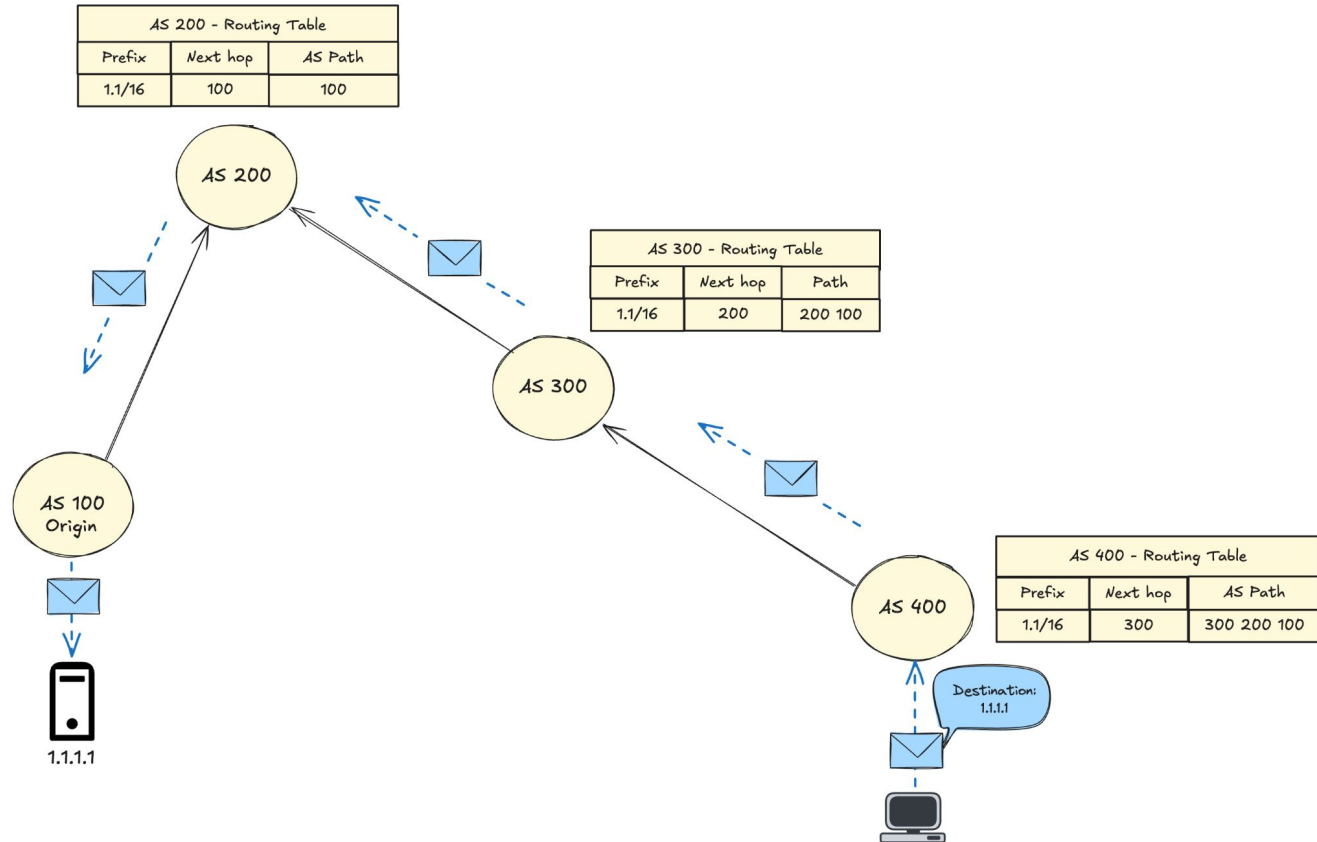
Border Gateway Protocol (BGP)



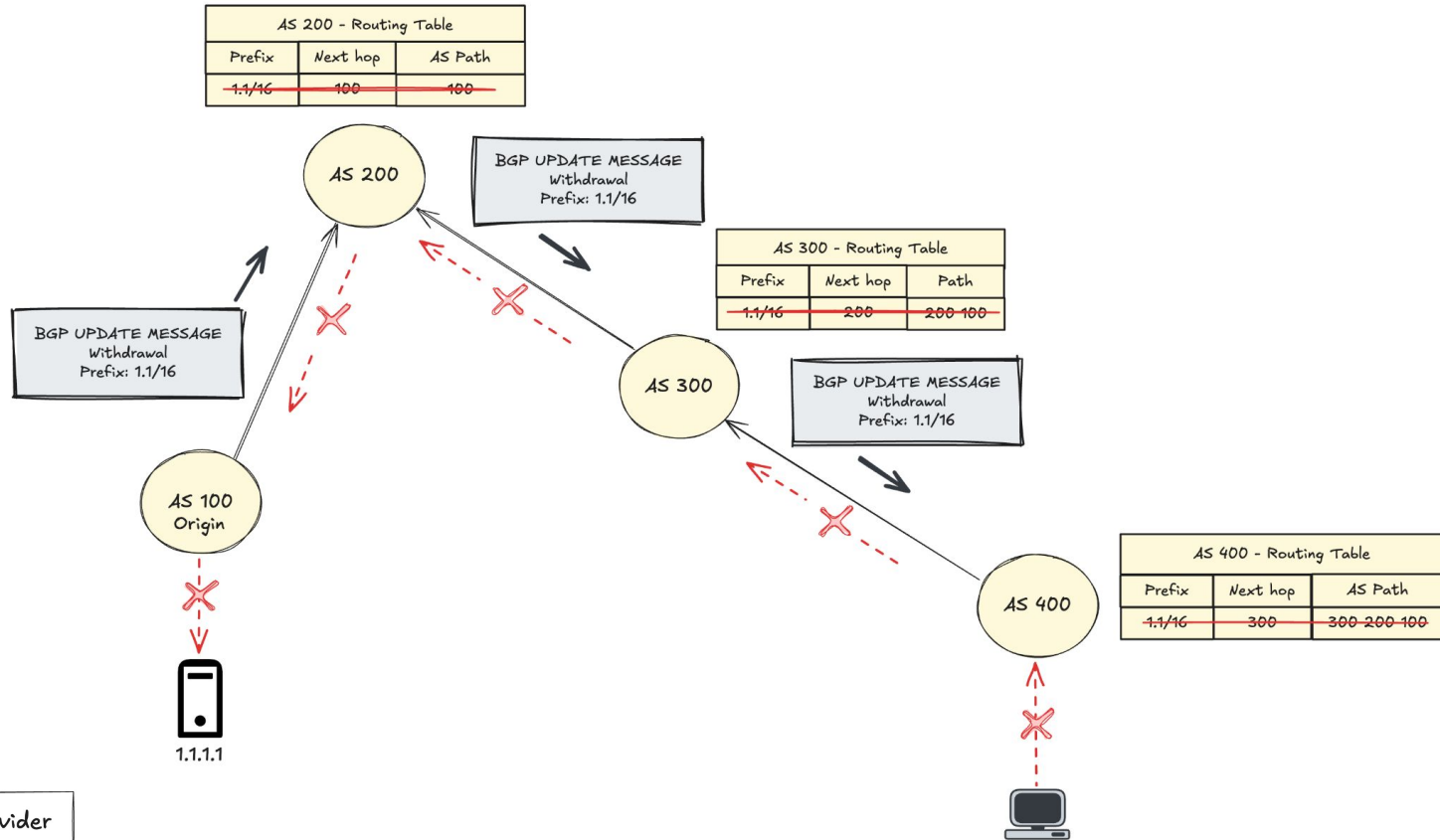
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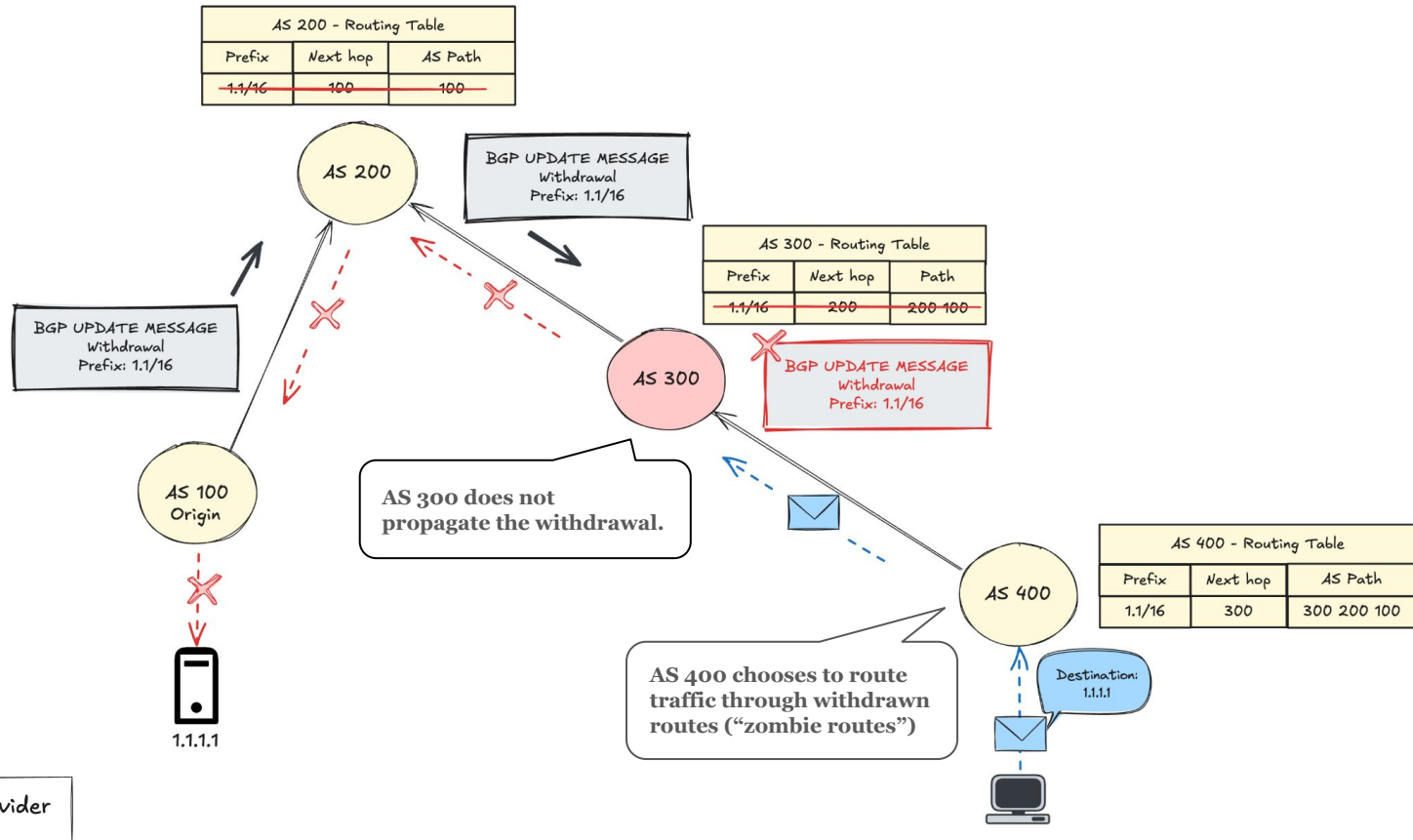
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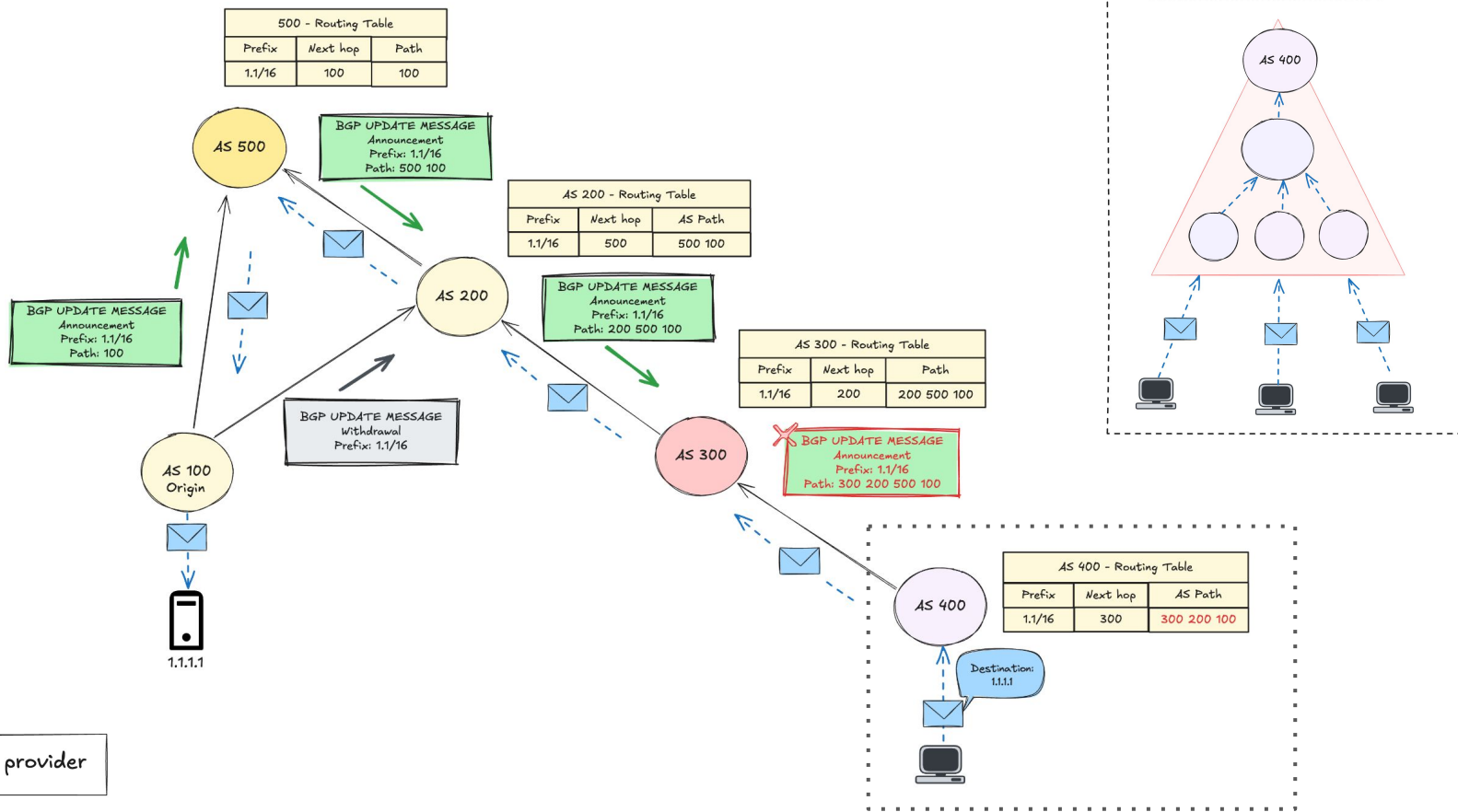
Explicit BGP Withdrawals



Withdrawal Suppression: BGP zombies/stuck routes



BGP Withdrawal Suppression with Implicit Withdrawal



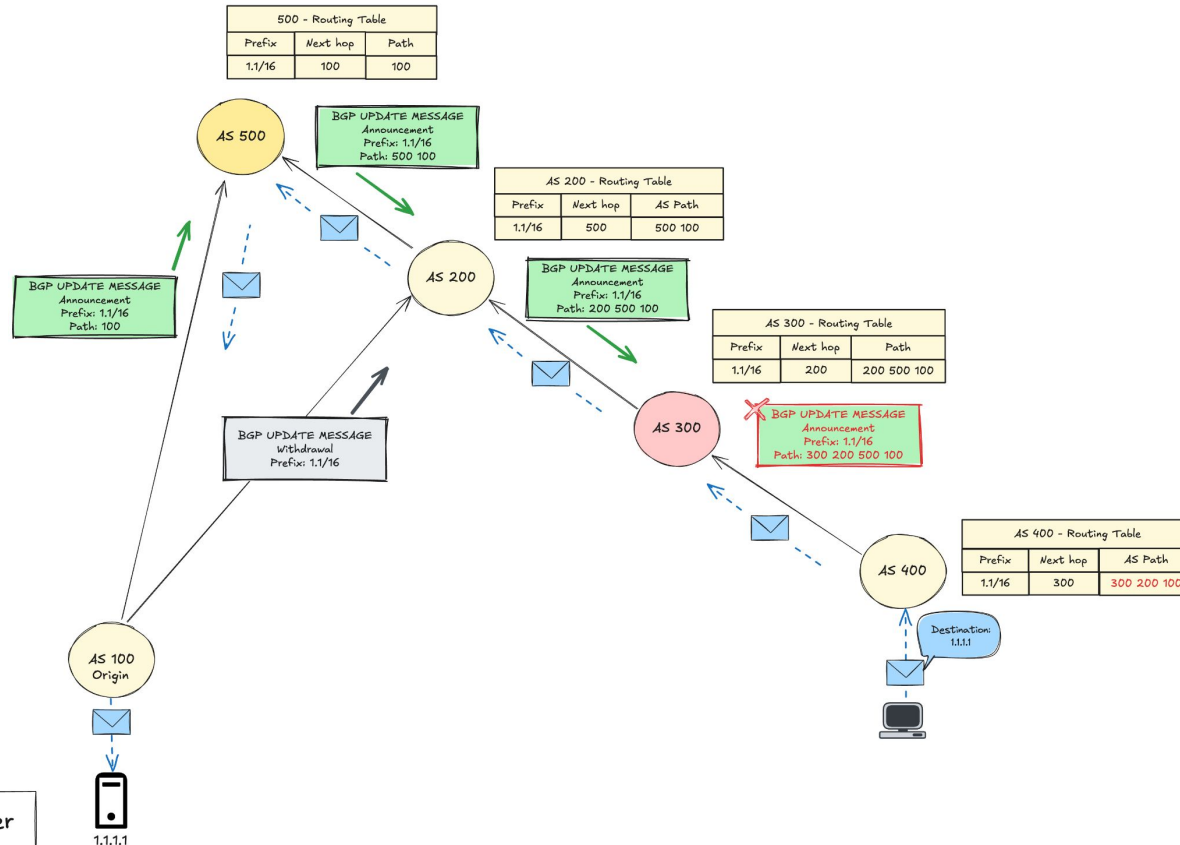
Zombie Routes - Impact on the Internet

- Suboptimal routing decisions
- Network instability
- Packet loss due to routing loops

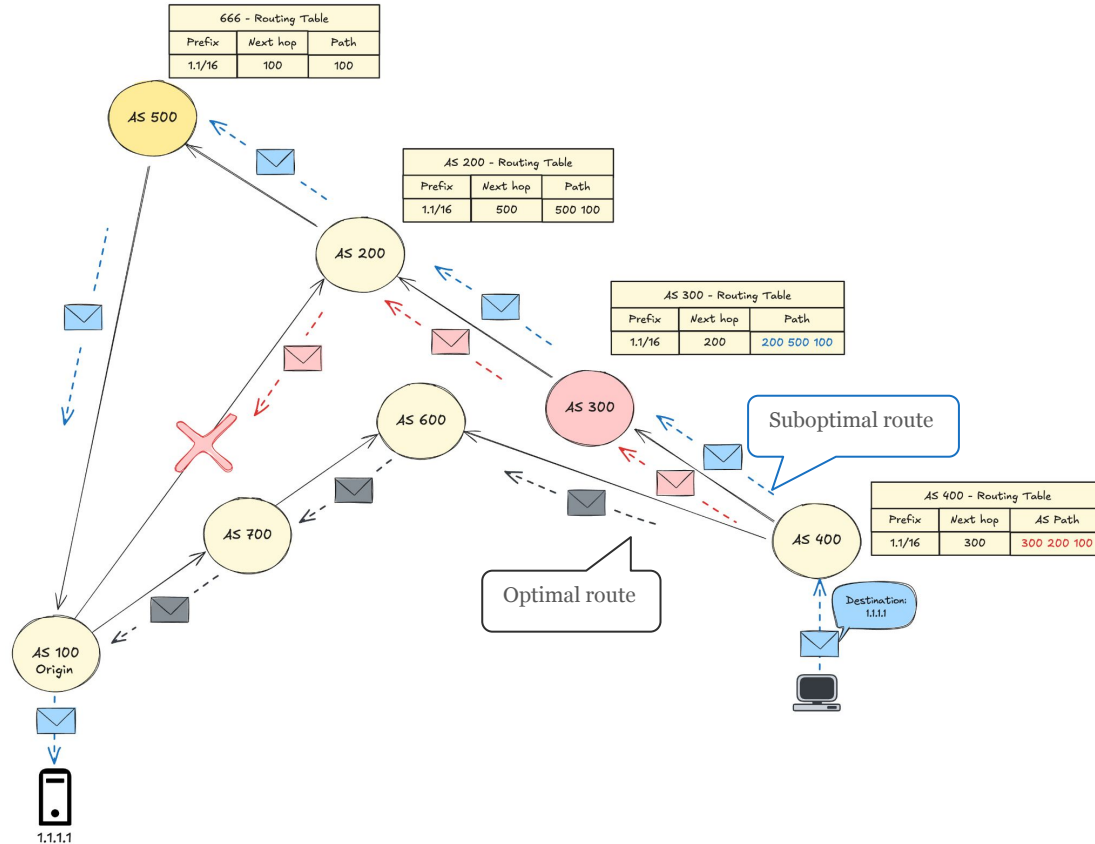
Zombie Routes - Impact on the Internet

- **Suboptimal routing decisions**
- Network instability
- Packet loss due to routing loops

Zombie Routes - Impact on the Internet (Suboptimal Routing)

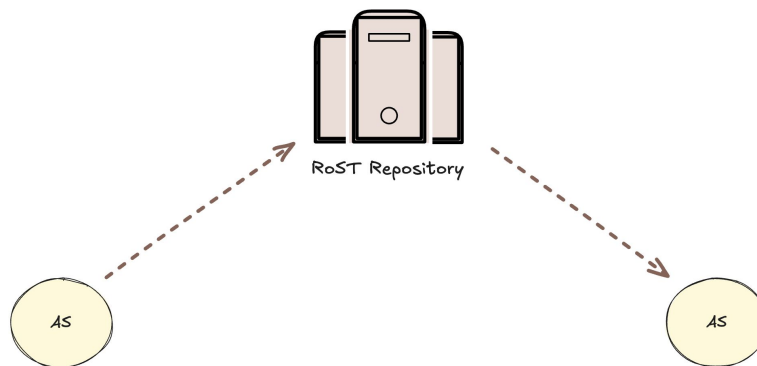


Zombie Routes - Impact on the Internet (Suboptimal Routes)



Route Status Transparency (RoST) - This work

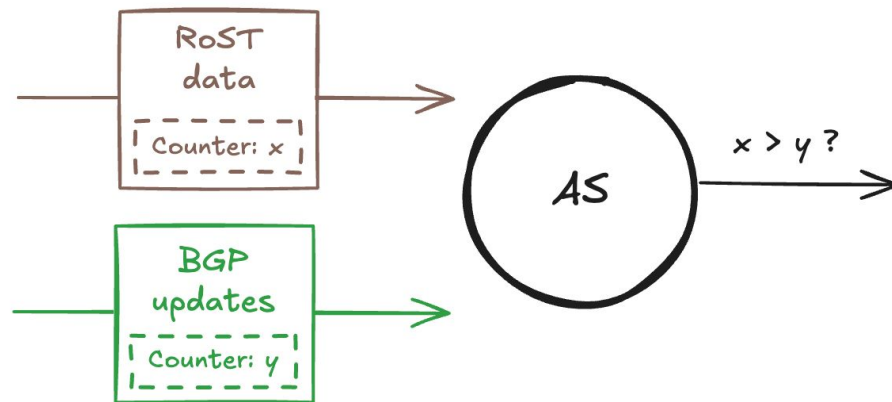
1. Periodically send to a *repository* status of routes announced
2. Validate own active routes by retrieving routes status of other ASes from the *repository*



Information exchanged with the repository can be authenticated using RPKI certificates.

RoST Synchronization

- Determine whether repository data or BGP update is more recent



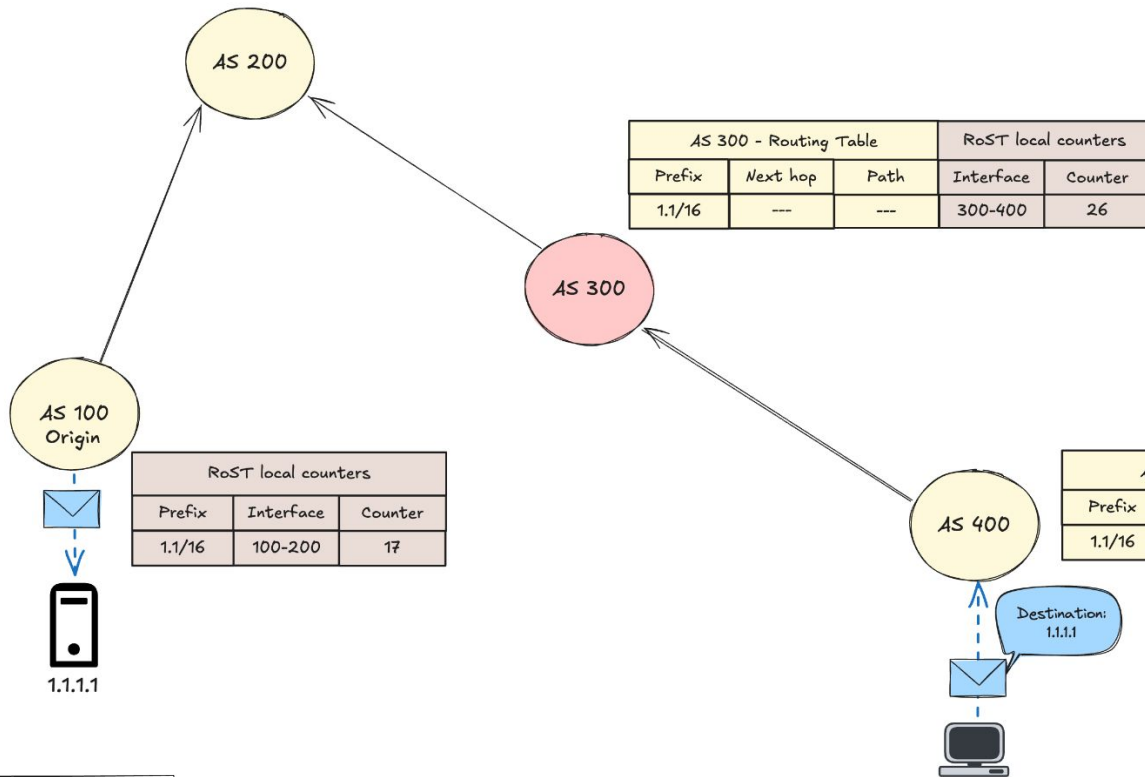
- RoST uses a *counter* in the BGP message indicating at what “time” the message was sent

Dealing with Frequent Route Changes

An IP route can change ~2M times/day (e.g route flapping)

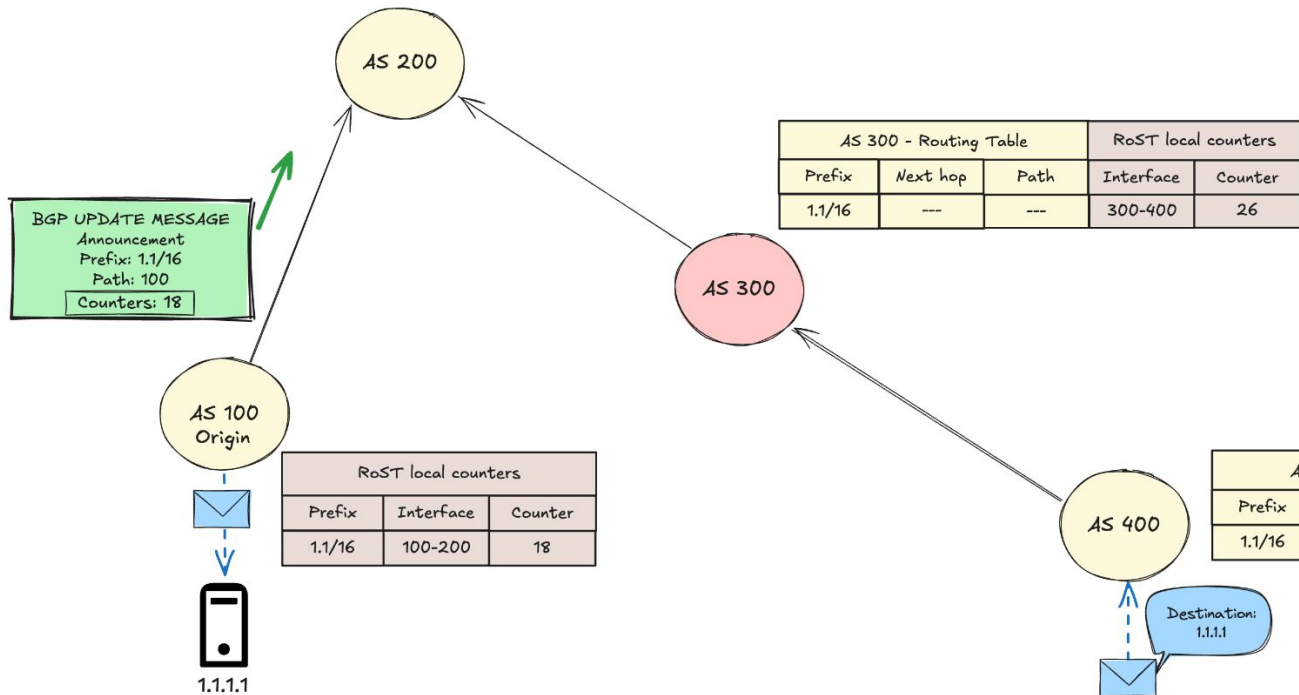
- Periodically send batch of delta path changes to the repository

AS 200 - Routing Table			RoST local counters	
Prefix	Next hop	AS Path	Interface	Counter
1.1/16	---	---	200-300	35



customer → provider

AS 200 - Routing Table			RoST local counters	
Prefix	Next hop	AS Path	Interface	Counter
1.1/16	100	100	200-300	35



customer —————> provider

AS 200 - Routing Table			RoST local counters	
Prefix	Next hop	AS Path	Interface	Counter
1.1/16	100	100	200-300	36

BGP UPDATE MESSAGE
Announcement
Prefix: 1.1/16
Path: 200 100
Counters: 36-18

AS 300 - Routing Table			RoST local counters	
Prefix	Next hop	Path	Interface	Counter
1.1/16	200	200 100	300-400	26

BGP UPDATE MESSAGE
Announcement
Prefix: 1.1/16
Path: 100
Counters: 18

AS 100
Origin



1.1.1.1

RoST local counters		
Prefix	Interface	Counter
1.1/16	100-200	18

AS 300

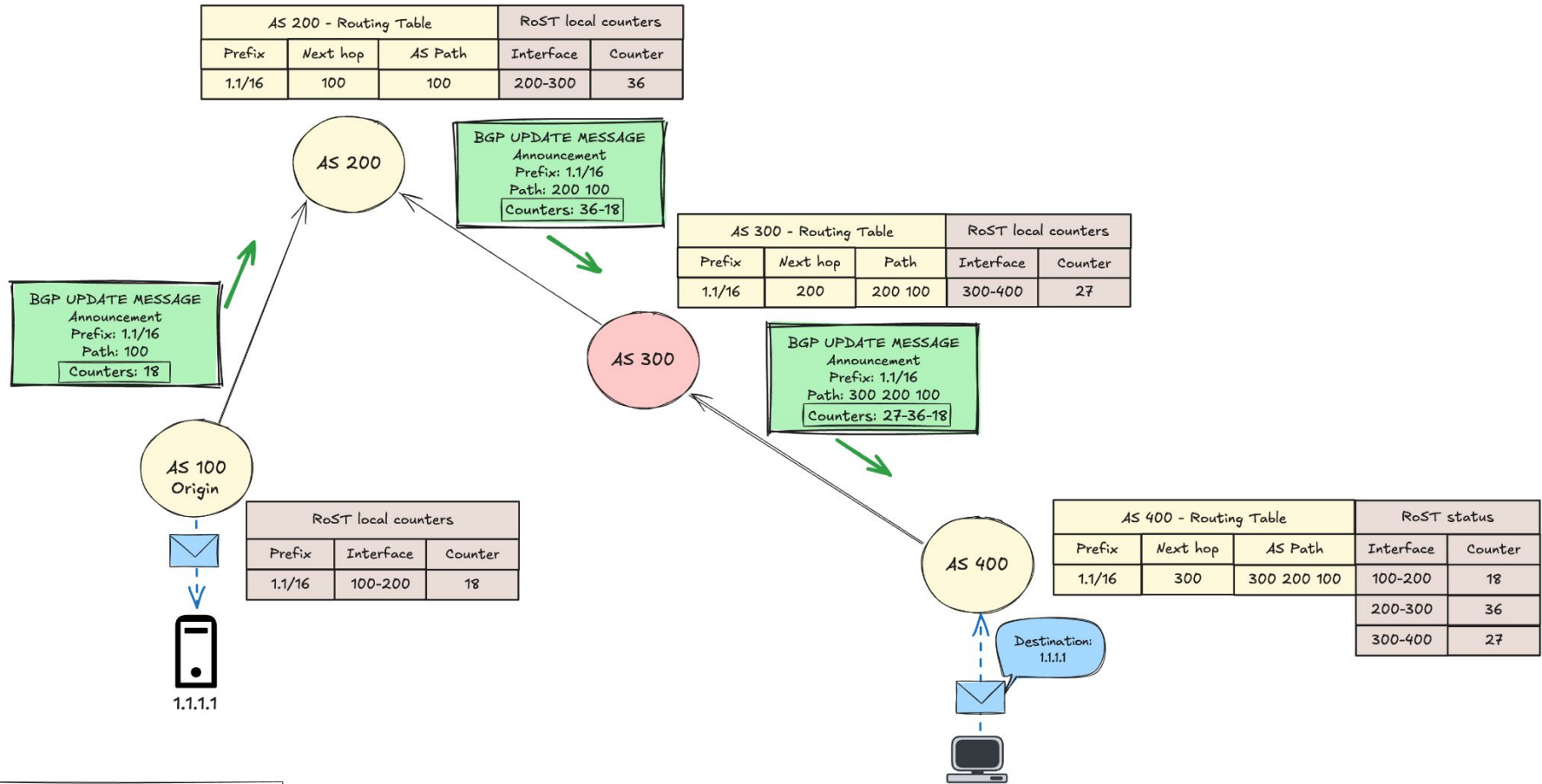
AS 400

AS 400 - Routing Table			RoST status	
Prefix	Next hop	AS Path	Interface	Counter
1.1/16	---	---	100-200	---
			200-300	---
			300-400	---

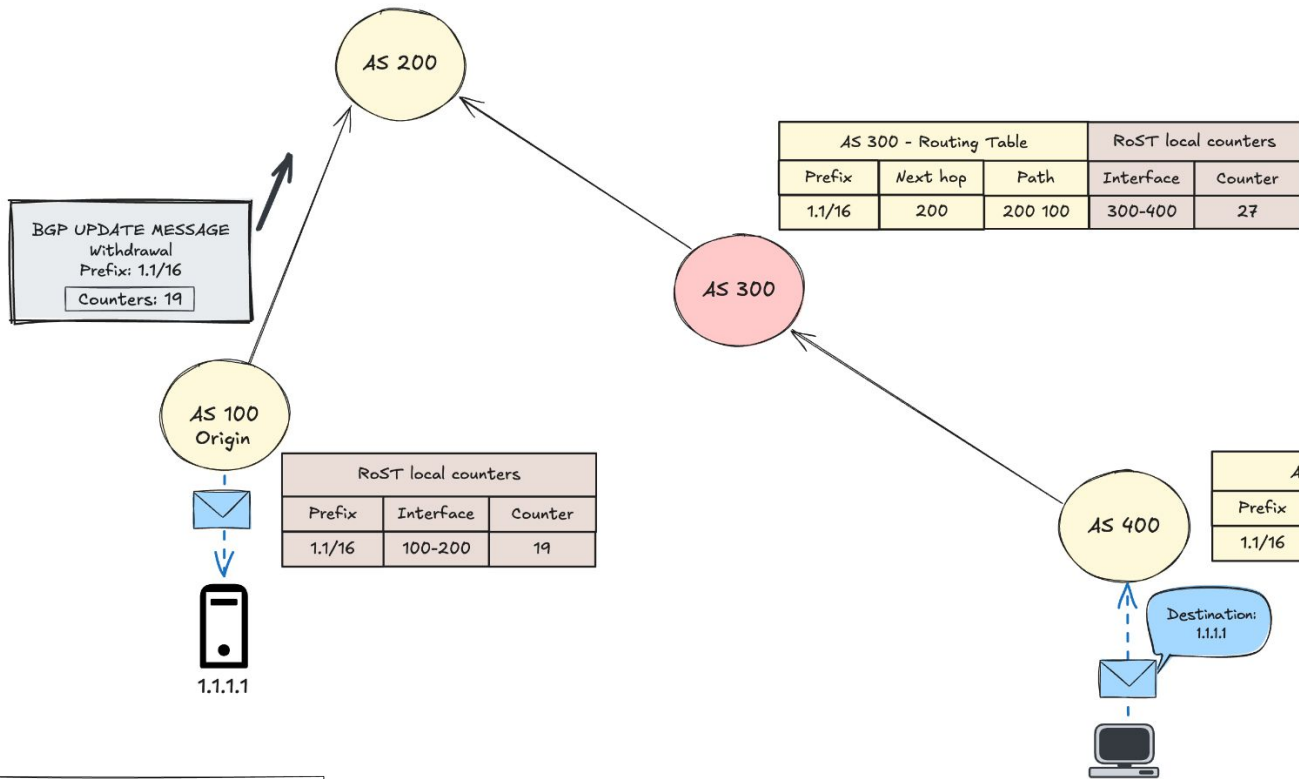
Destination:
1.1.1.1



customer → provider



AS 200 - Routing Table			RoST local counters	
Prefix	Next hop	AS Path	Interface	Counter
1.1/16	100	100	200-300	36



AS 200 - Routing Table			RoST local counters	
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1.1/16	100	100	200-300	37

BGP UPDATE MESSAGE
Withdrawal
Prefix: 1.1/16
Counters: 37-19

AS 300 - Routing Table			RoST local counters	
Prefix	Next hop	Path	Interface	Counter
1.1/16	200	200 100	300-400	27

BGP UPDATE MESSAGE
Withdrawal
Prefix: 1.1/16
Counters: 19

AS 100
Origin

RoST local counters		
Prefix	Interface	Counter
1.1/16	100-200	19



1.1.1.1

AS 300

AS 400

AS 400 - Routing Table			RoST status	
Prefix	Next hop	AS Path	Interface	Counter
1.1/16	300	300 200 100	100-200	18
			200-300	36
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Destination:
1.1.1.1



customer → provider

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BGP UPDATE MESSAGE
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Prefix: 1.1/16
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AS 300 - Routing Table			RoST local counters	
Prefix	Next hop	Path	Interface	Counter
1.1/16	200	200-100	300-400	27

~~BGP UPDATE MESSAGE
Withdrawal
Prefix: 1.1/16~~

BGP UPDATE MESSAGE
Withdrawal
Prefix: 1.1/16
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AS 100
Origin



1.1.1.1

RoST local counters		
Prefix	Interface	Counter
1.1/16	100-200	19

AS 300

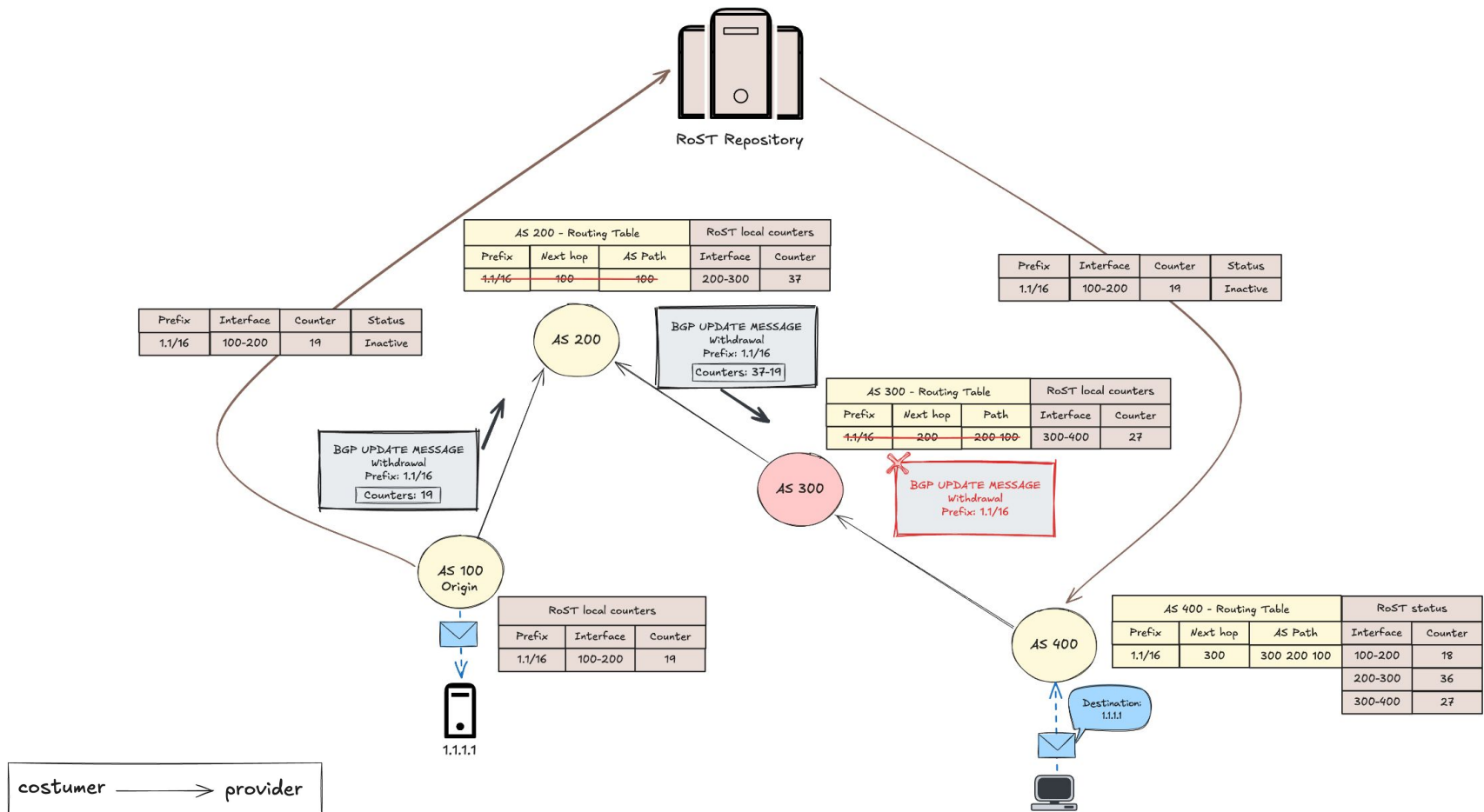
AS 400

AS 400 - Routing Table			RoST status	
Prefix	Next hop	AS Path	Interface	Counter
1.1/16	300	300 200 100	100-200	18
			200-300	36
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Destination:
1.1.1.1

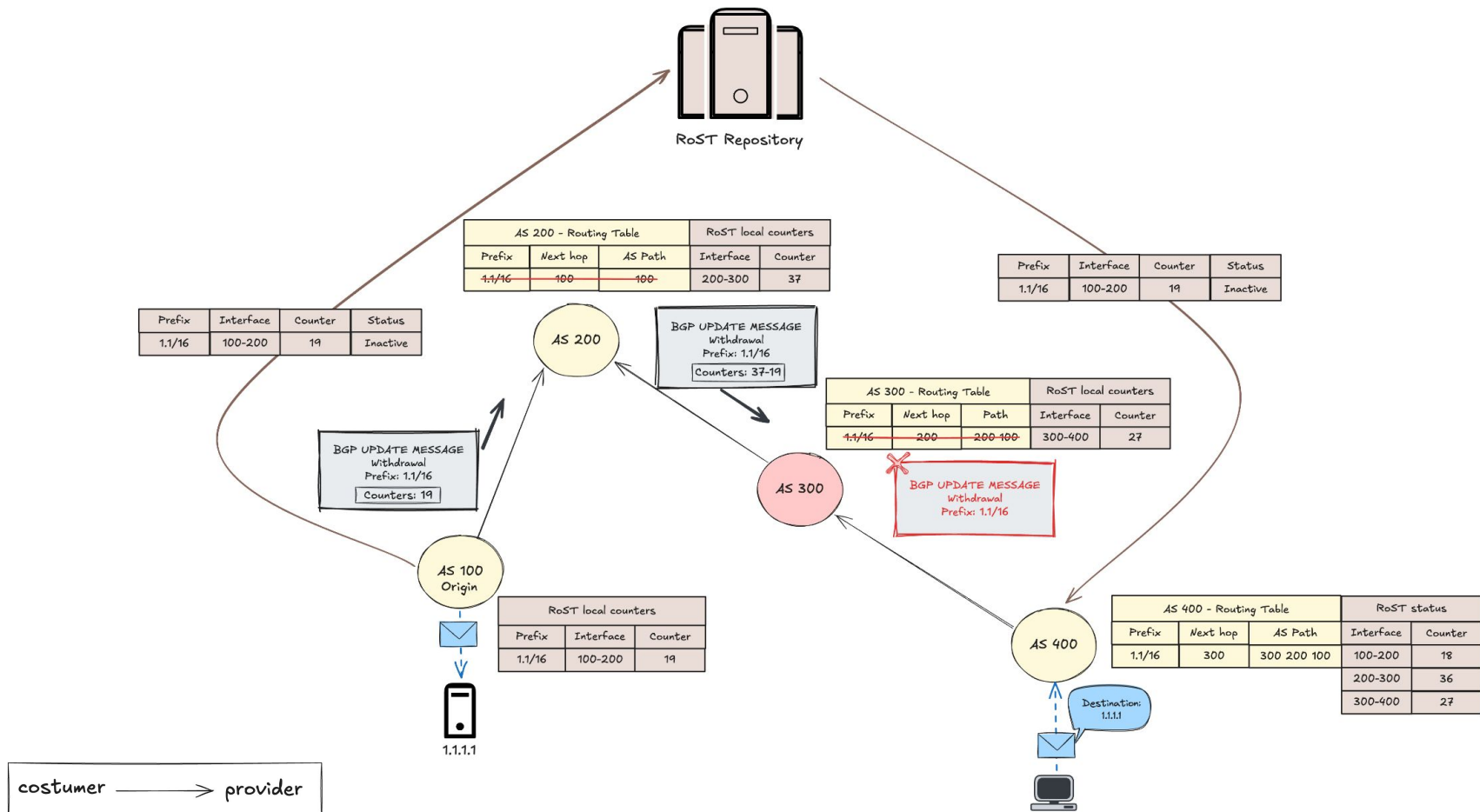


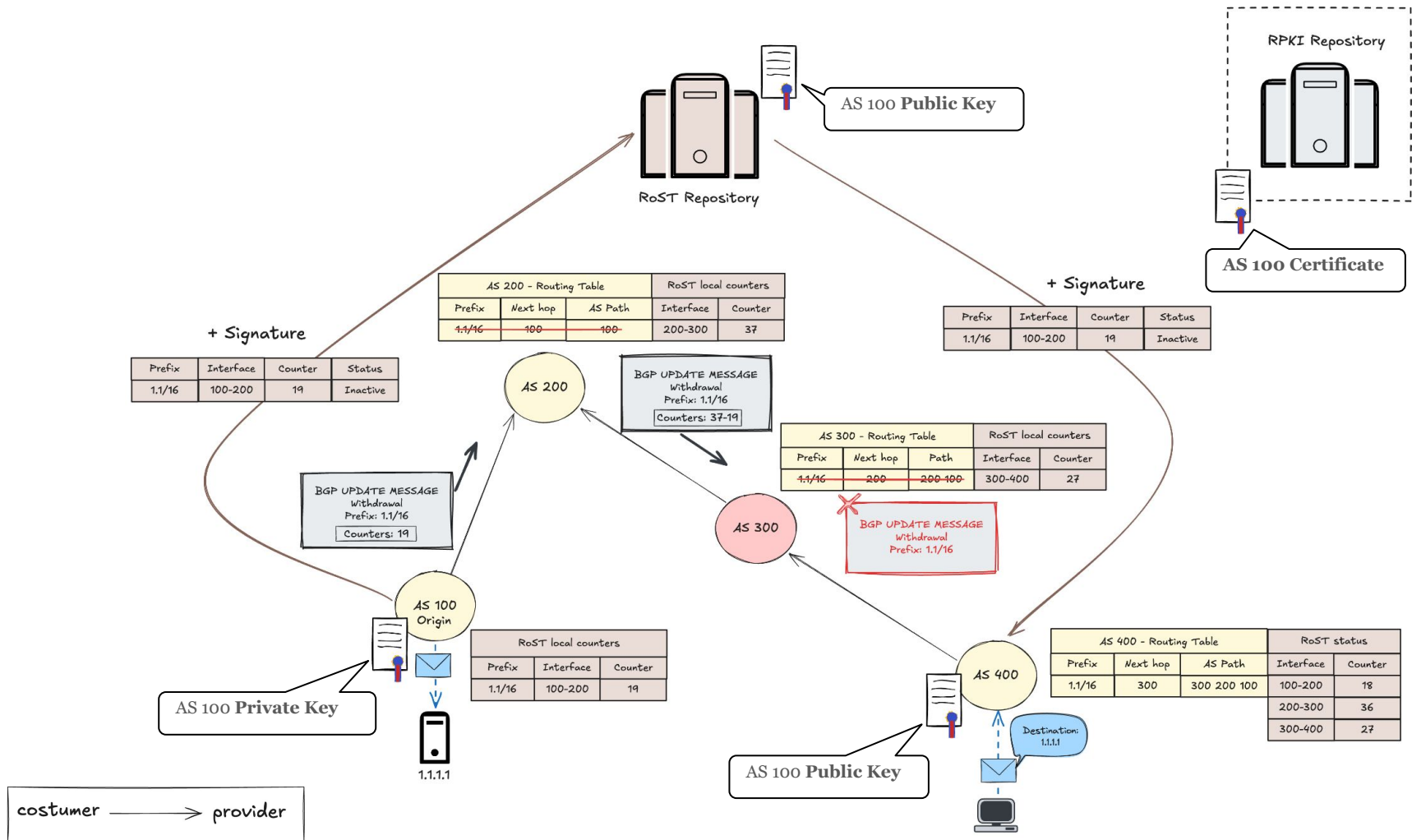
customer → provider



RoST Security - Dealing with malicious faults

- *Malicious repository*: RoST uses RPKI certificates (~55% of ASes have one)
- RoST uses this certificate to:
 - Sign route status updates uploads using it's private key
 - Repository and AS's validate data using the public key
- *Malicious ASes*: To prevent path manipulation and withdrawal suppressions use RoST with BGP-iSec (recently proposed)



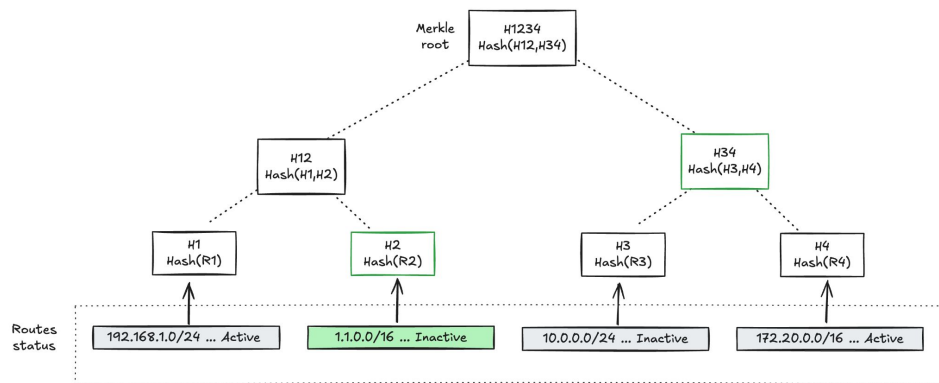


RoST Security - Selective Route Distribution

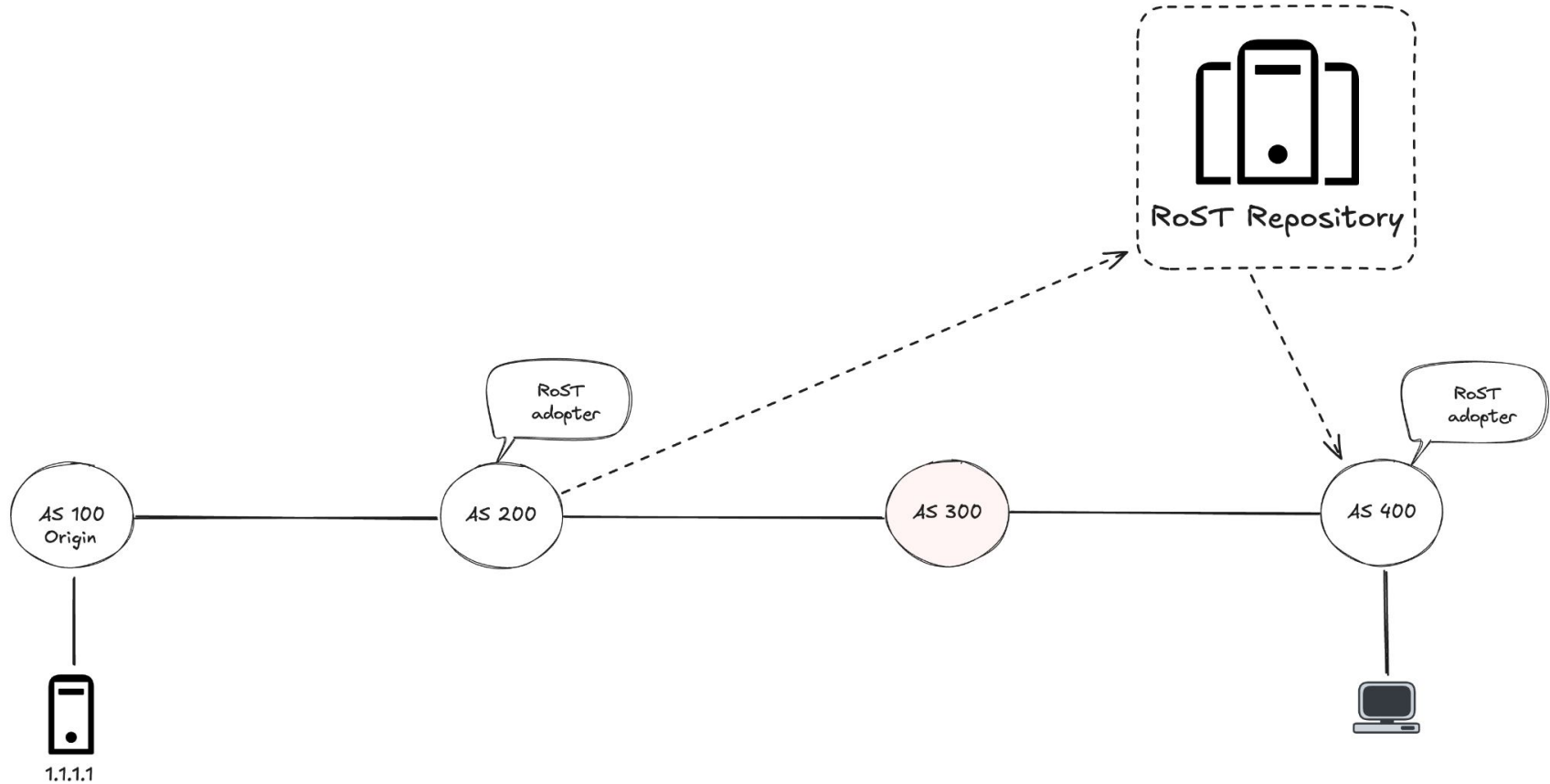
An AS does not need all routes (potentially millions for each interface; ~4 TB)

RoST approach:

- Publisher generates a Merkle root for all its exported routes at each batch
- Repository provides Merkle proofs for required subsets ensuring integrity with minimal data transfer



RoST Benefits Under Partial Adoption

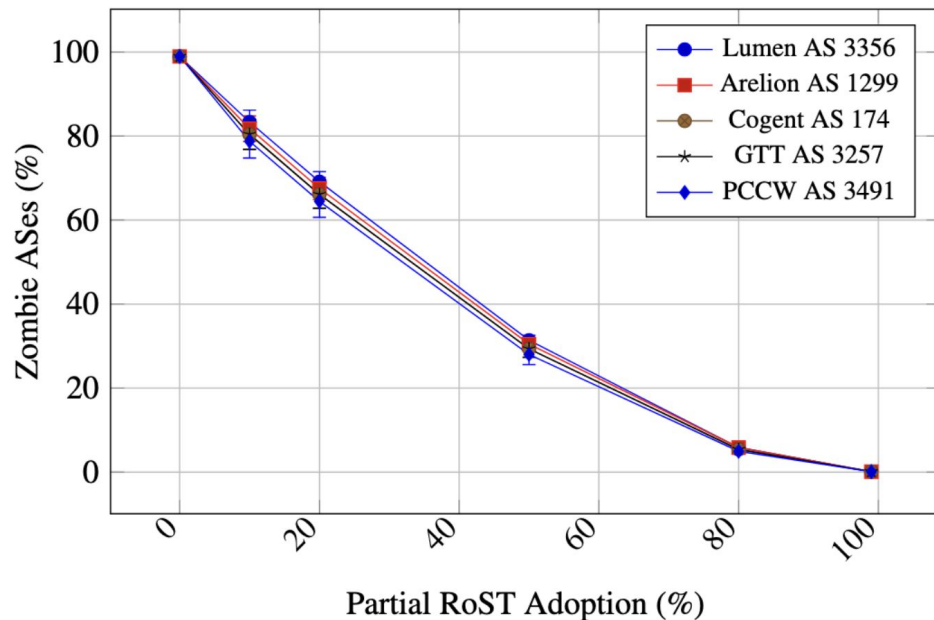


RoST Benefits Under Partial Adoption

Simulated BGP route selection over CAIDA's AS internet topology.

Scenario:

1. The origin AS announces a prefix and later withdraws it
2. A Tier-1 AS fails to propagate the withdrawal (*zombie route*)

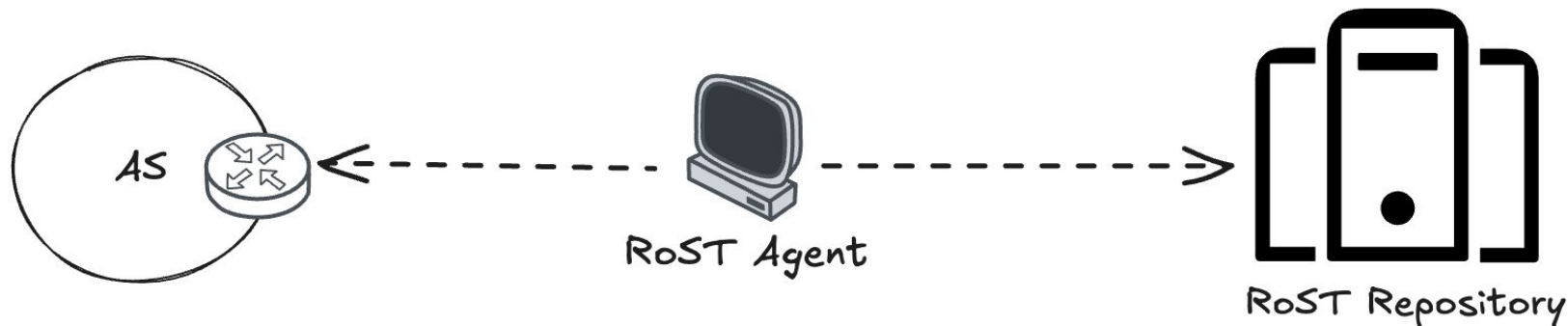


RoST Overhead at 100% Deployment

Metric	Overhead
Storage (per AS)	Up to 100 MiB
Storage (repository total)	Up to 8 TiB
Bandwidth (per AS, 5 min updates)	Less than 100 Kbps

RoST Compatibility with Existing Routers

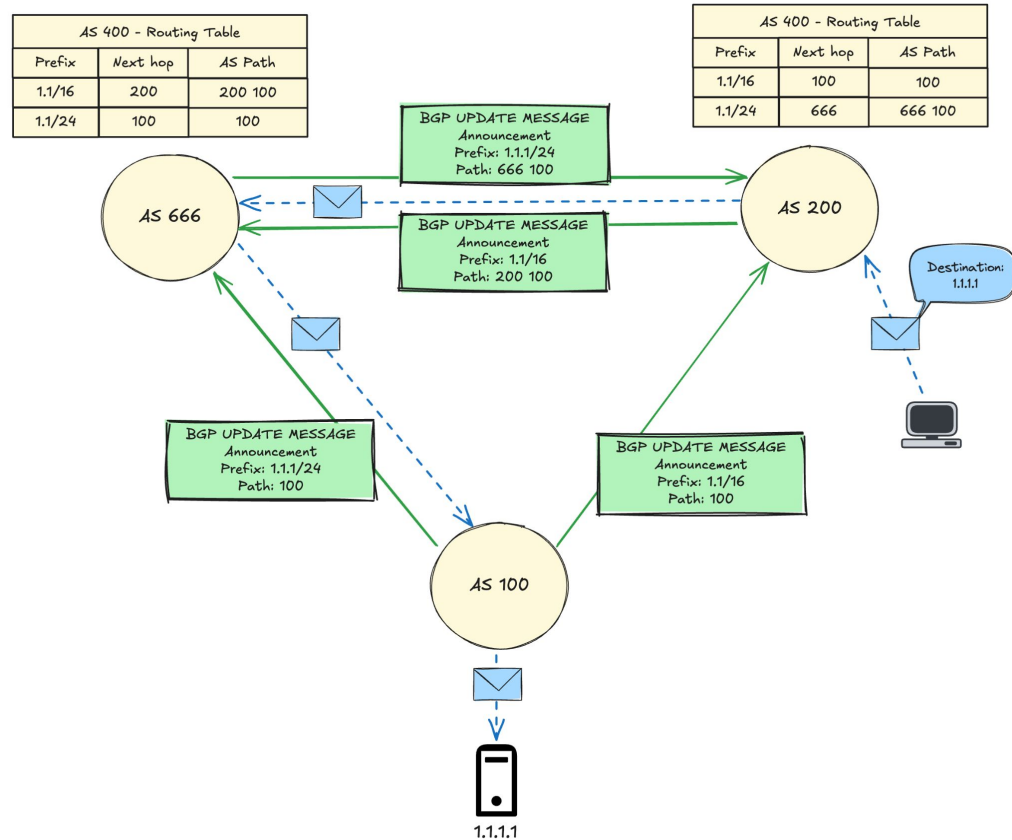
- Upgrading all BGP routers (hardware/software) is expensive
- External agent implements RoST and communicates with routers via API



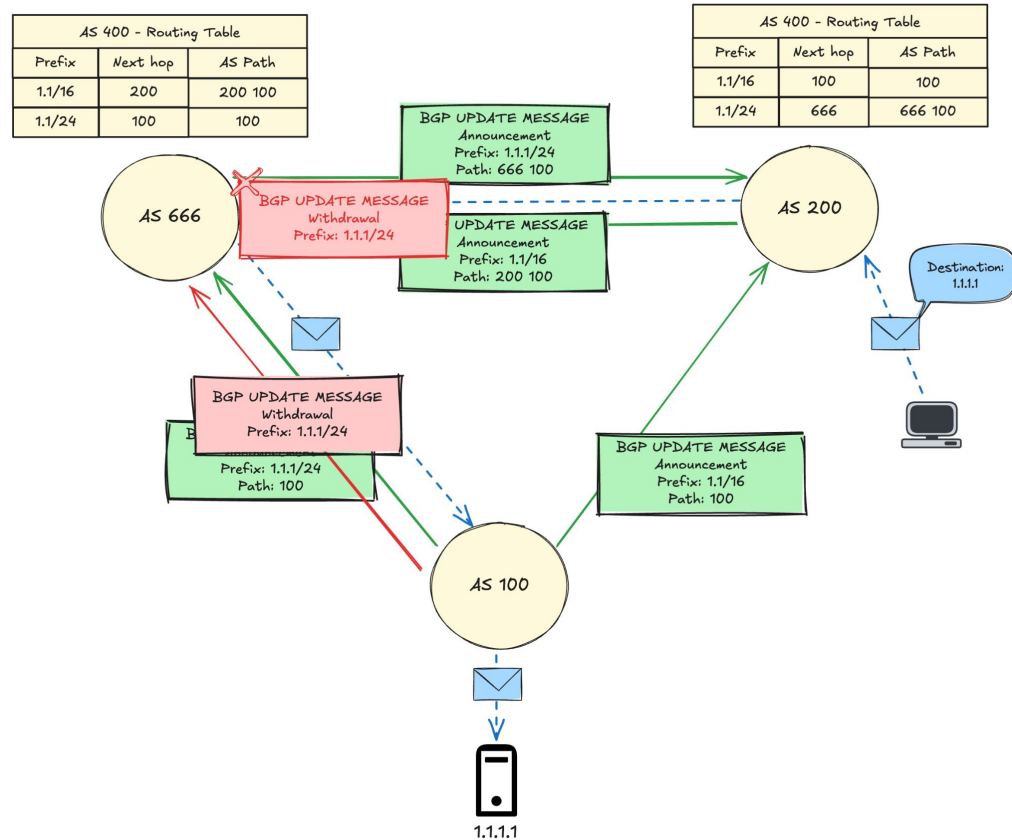
Summary

- *Problem:* BGP withdrawal suppression creates zombie routes (suboptimal routing, instability, possible loops)
- *Solution (RoST):* ASes upload and retrieve routes status from/to a repository
- *Security:* Information can be signed using RPKI certificates
- *Benefits:* Works well in partial adoption and it can be easily deployed

Zombie Routes - Impact on the Internet (Routing Loops)



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