The Ethereum Consensus Network has a Privacy Issue

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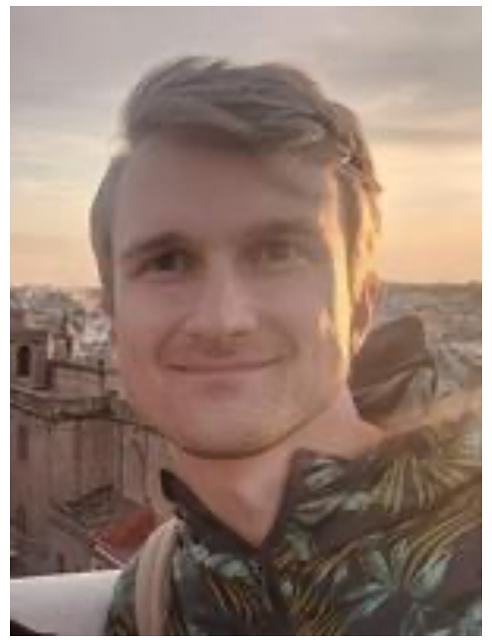
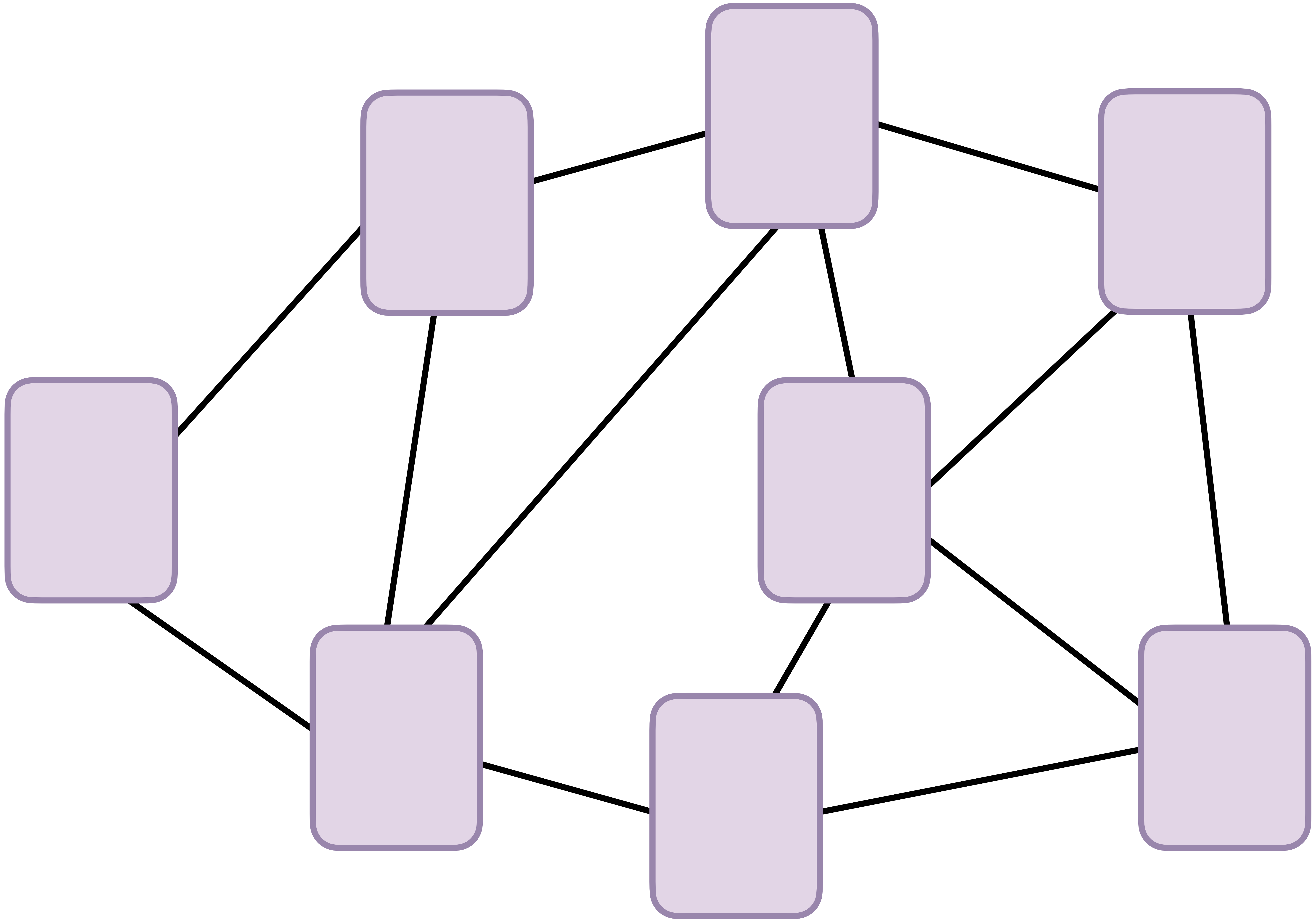
Lioba Heimbach
ETH Zurich

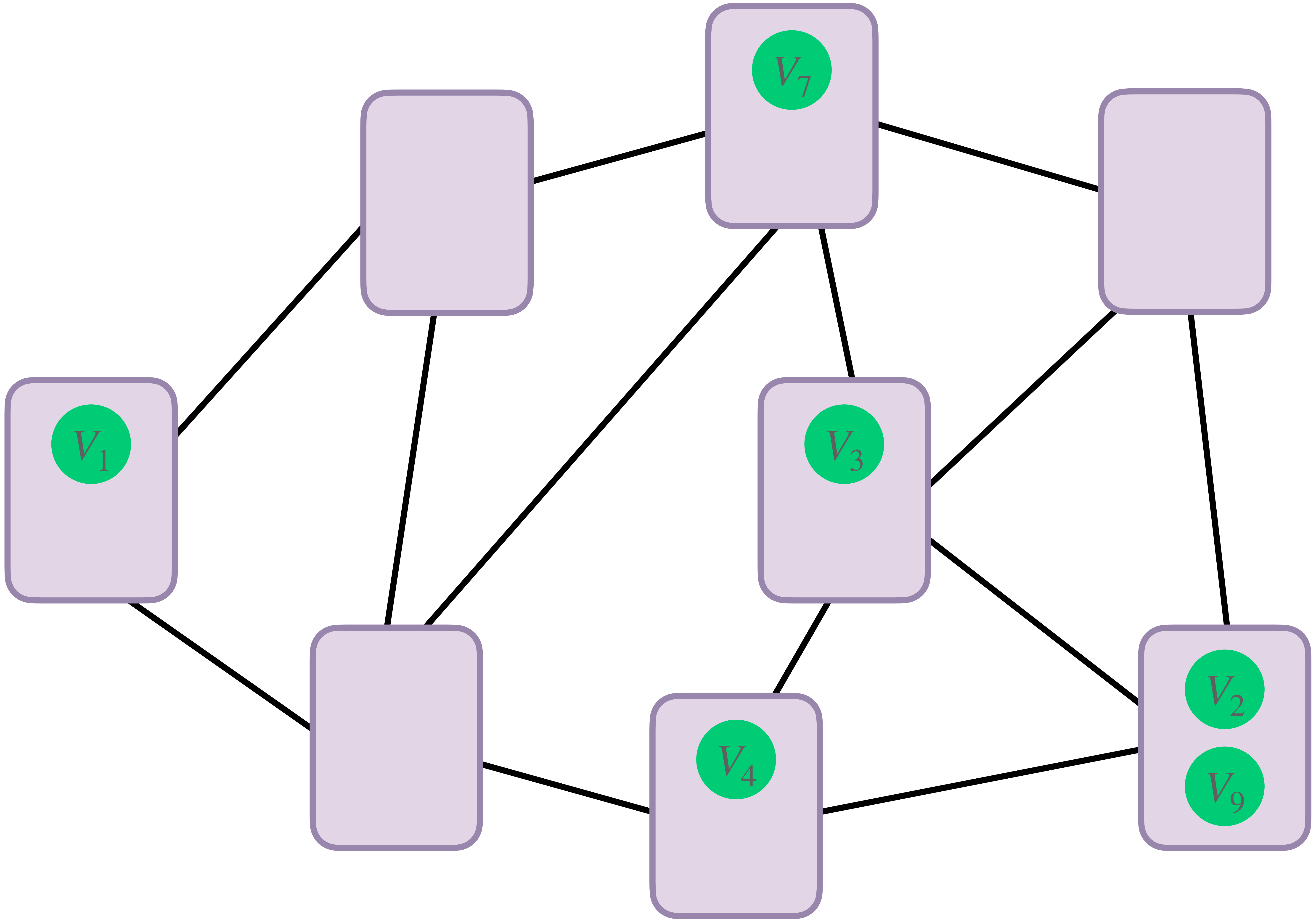


Yann Vonlathen
ETH Zurich

Juan Villacis
University of Bern

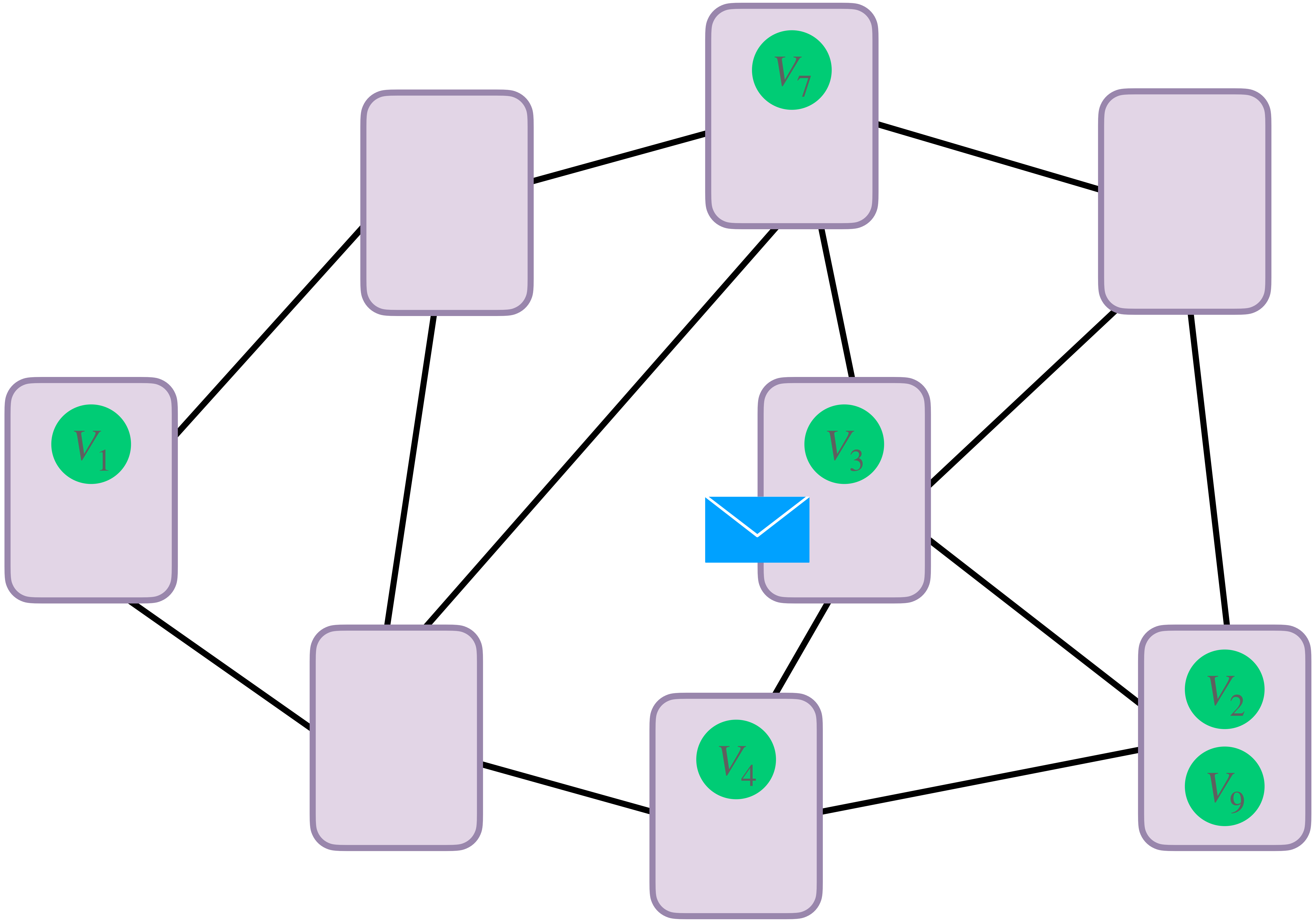
Prof. Roger Wattenhofer
ETH Zurich




V_7
V_1
V_3
V_4
V_2
V_9

Validator

- Entities **in charge of consensus**
- Have unique Validator ID (per 32 ETH)


V_7
V_1
V_3
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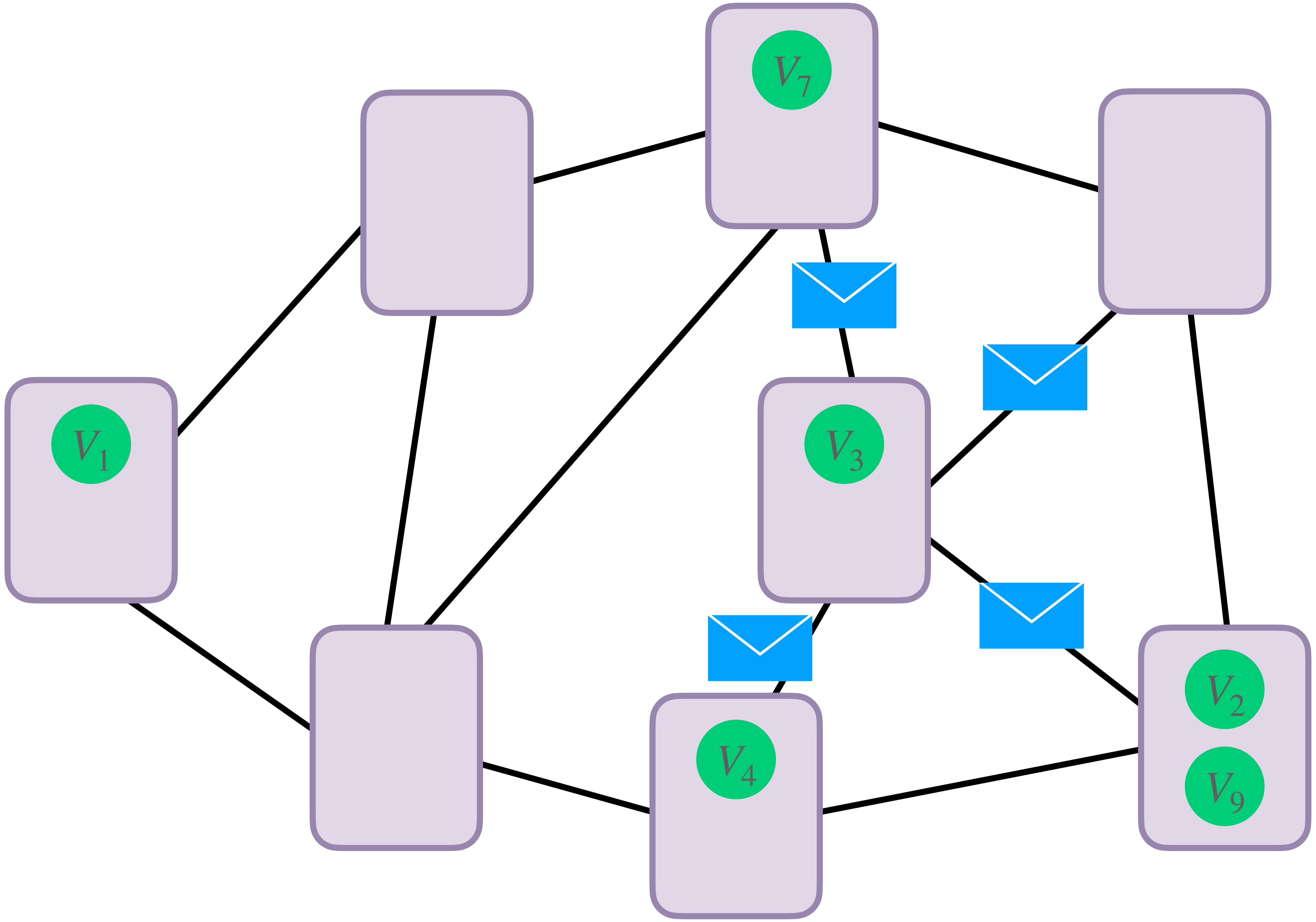
V_9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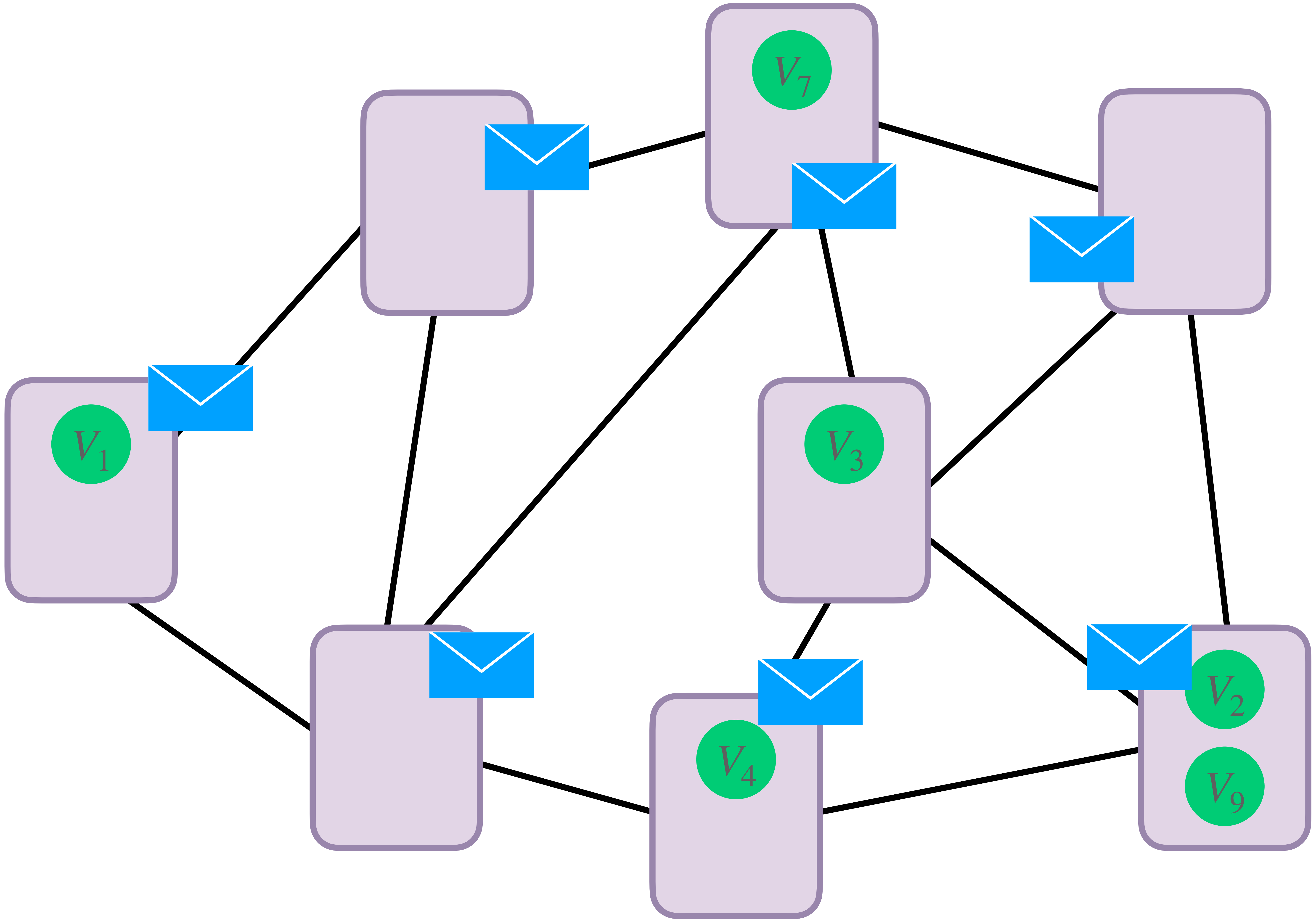
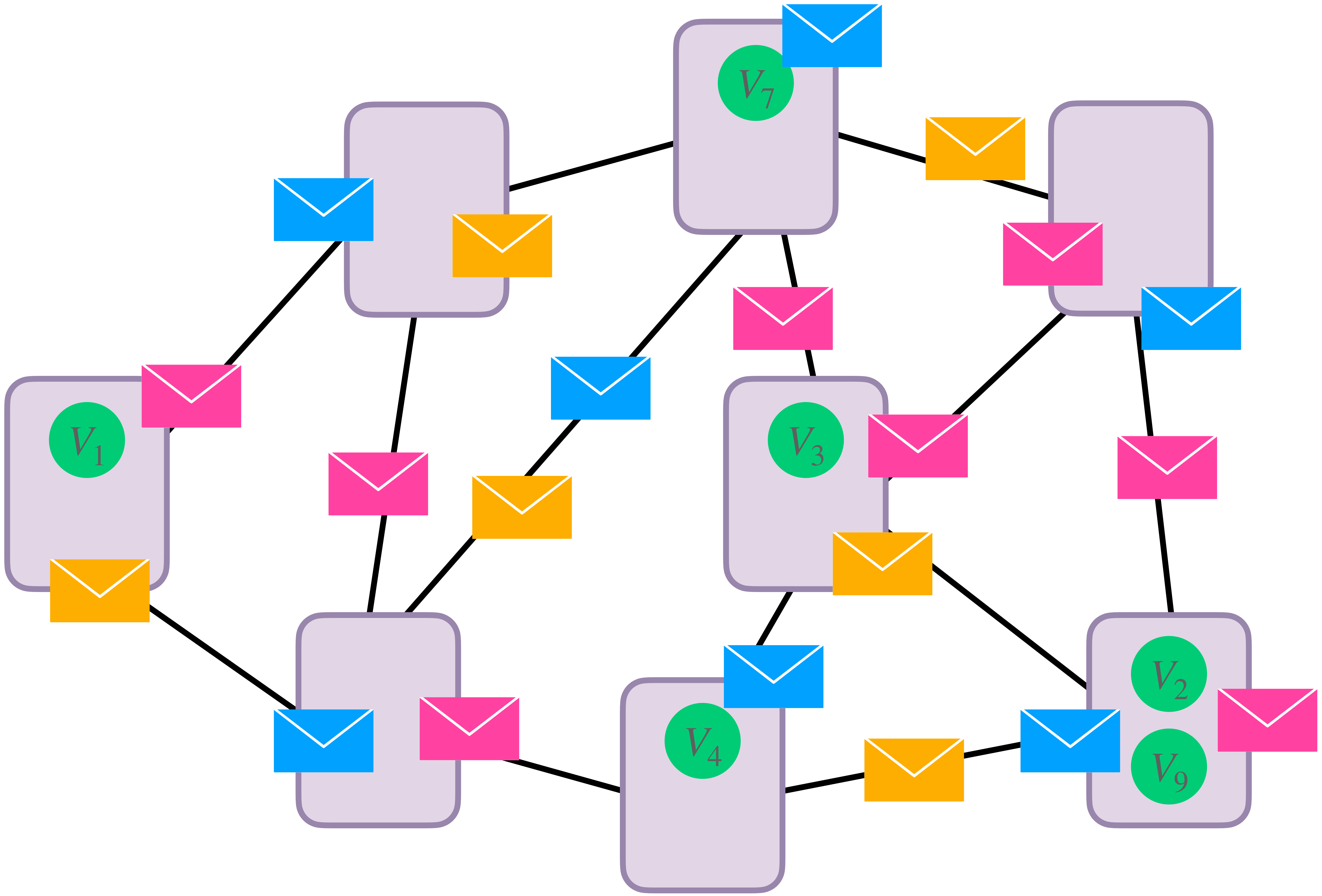
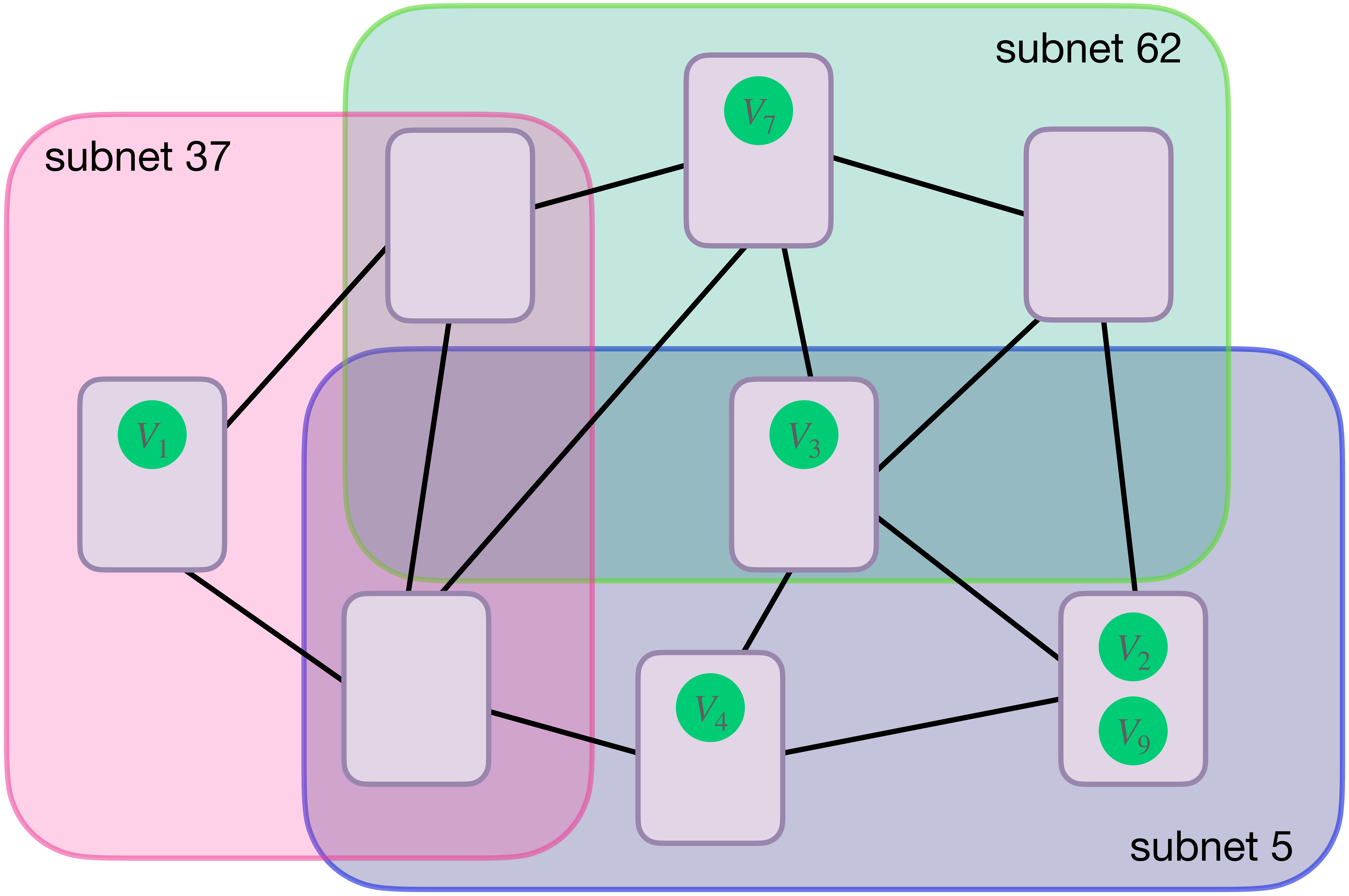
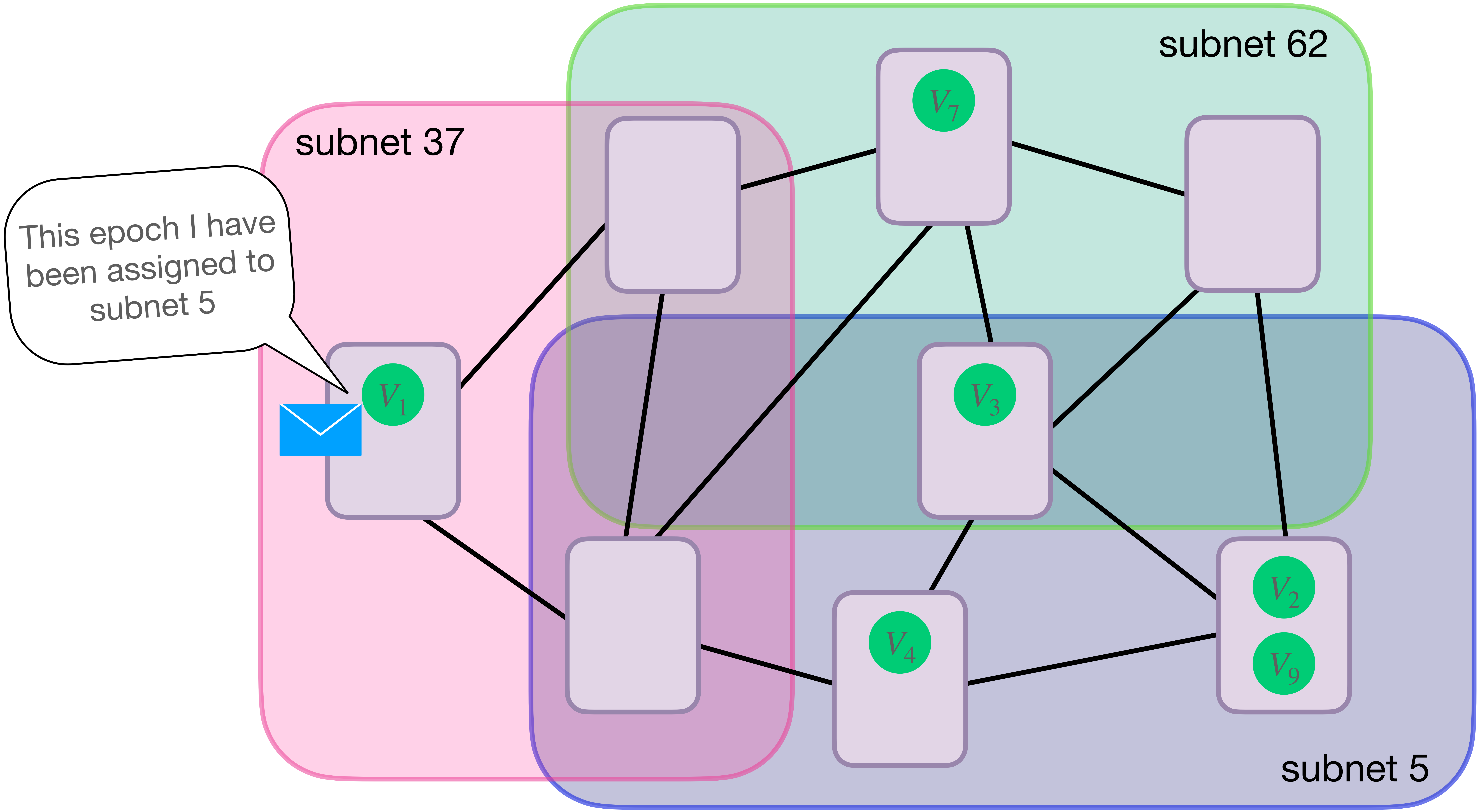
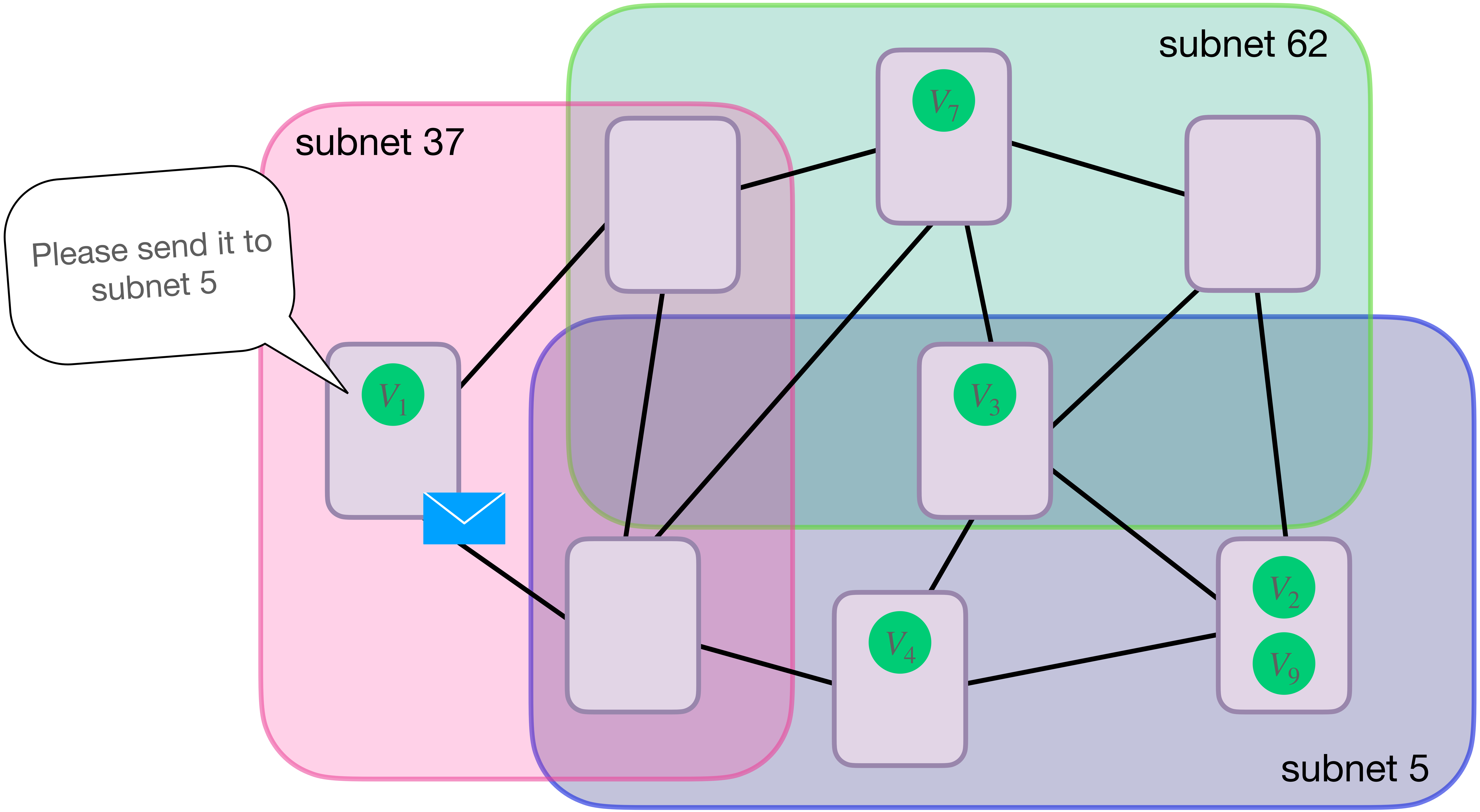
V_1
V_3
V_4
V_2
V_9

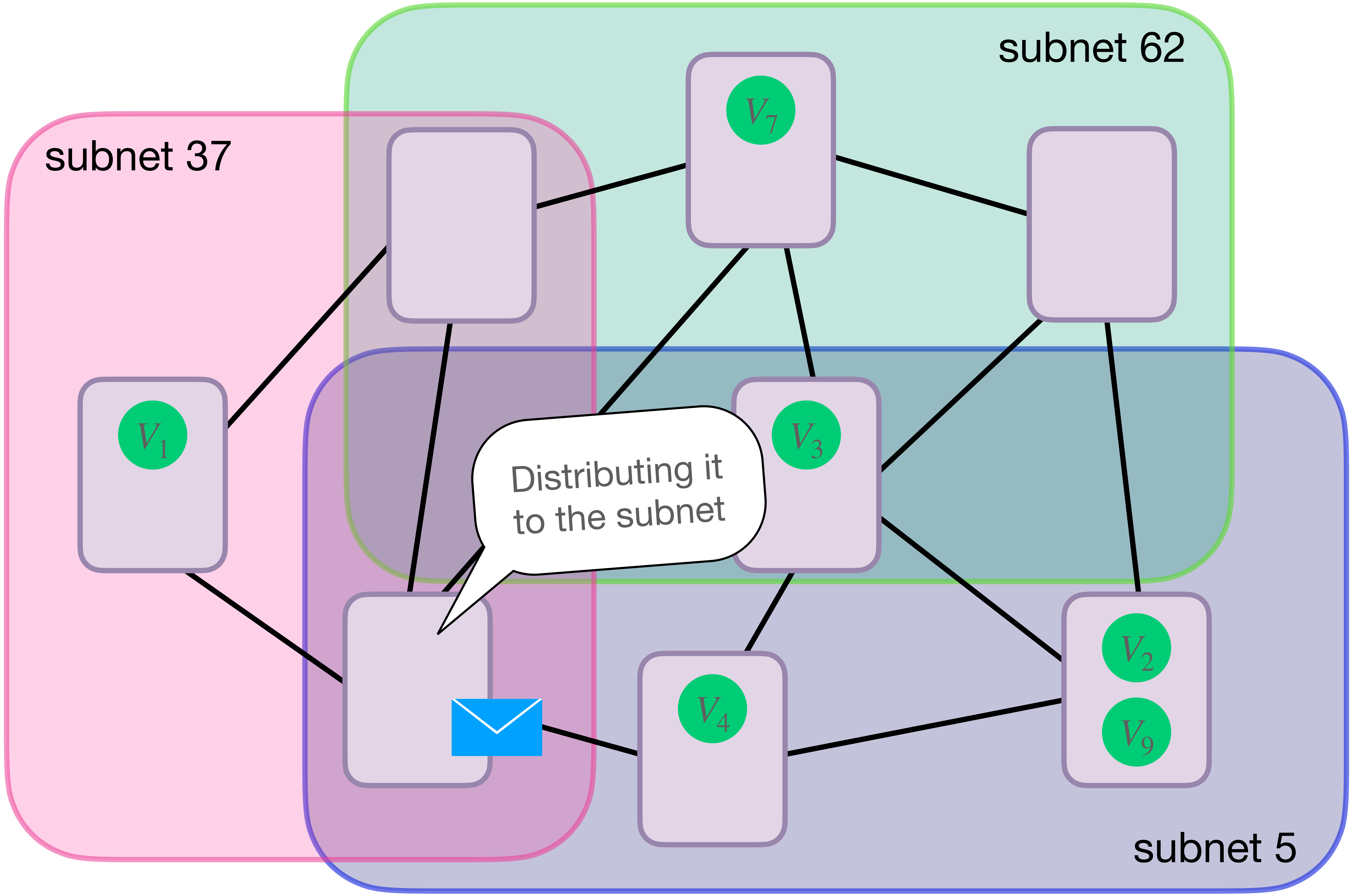

V_7
V_1
V_3
V_4
V_2
V_9

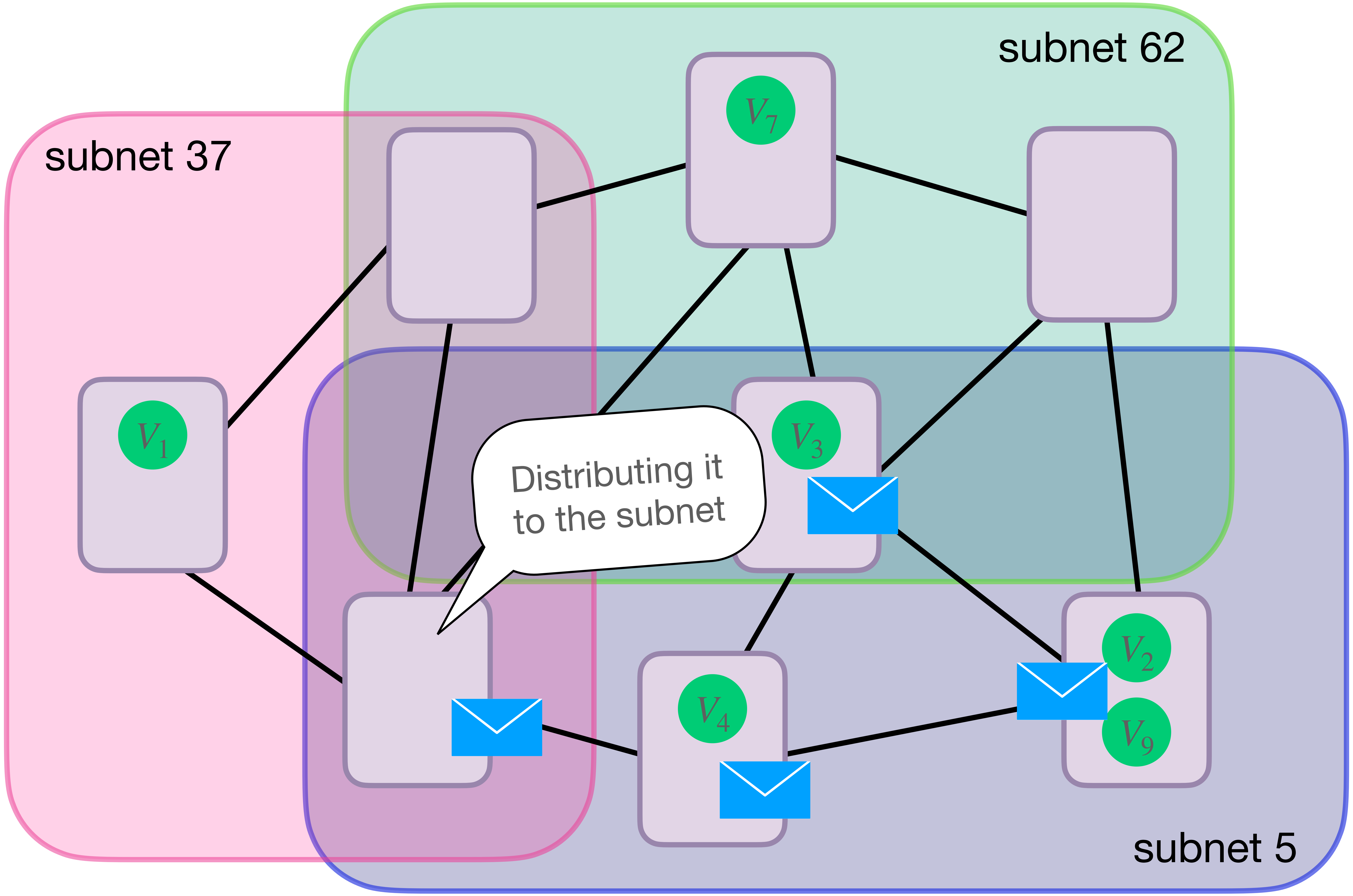

V_7
V_1
V_3
V_2
V_4
V_9

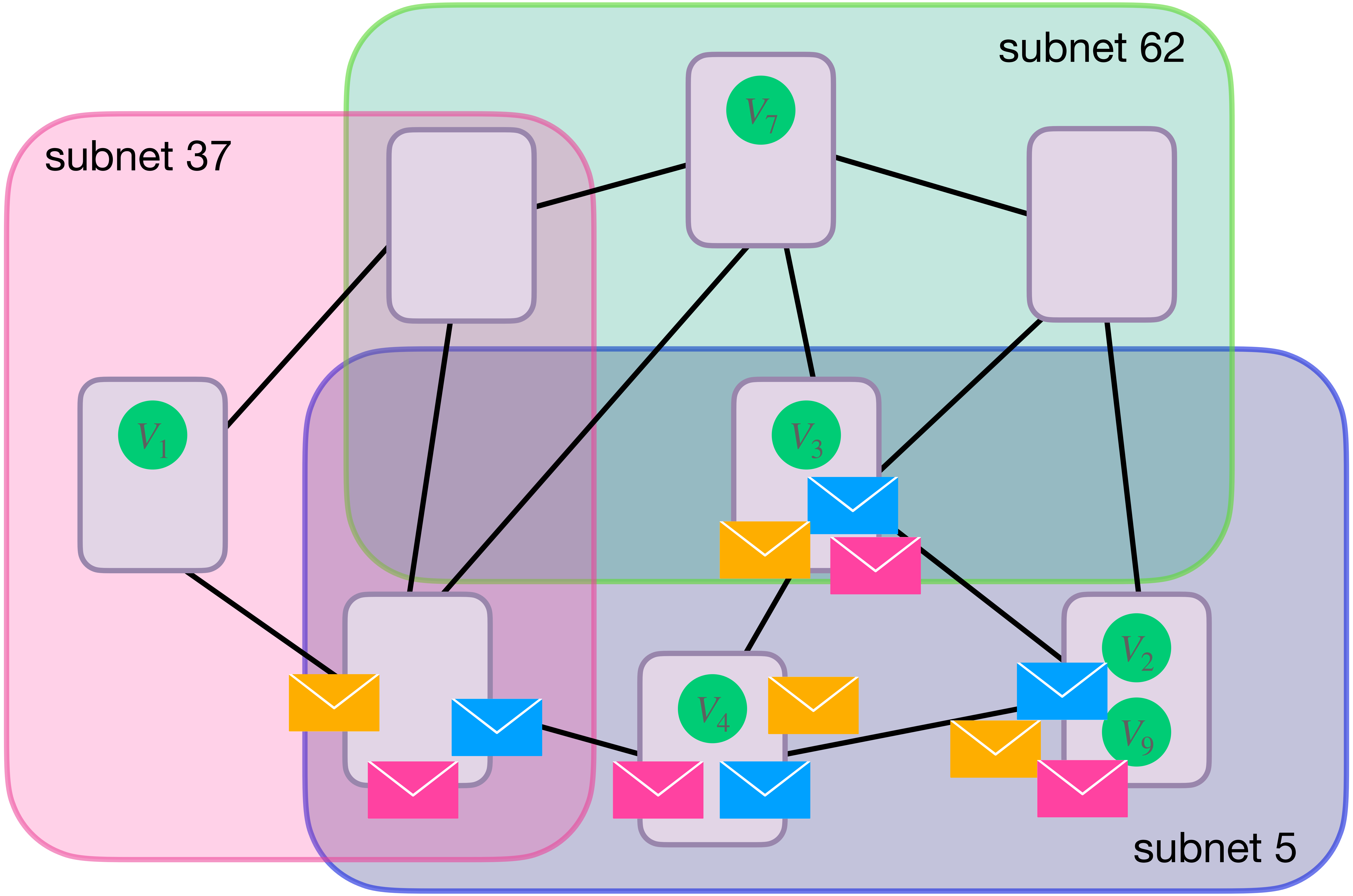

subnet 62
subnet 37
V_7
V_1
V_3
V_4
V_2
V_9
subnet 5

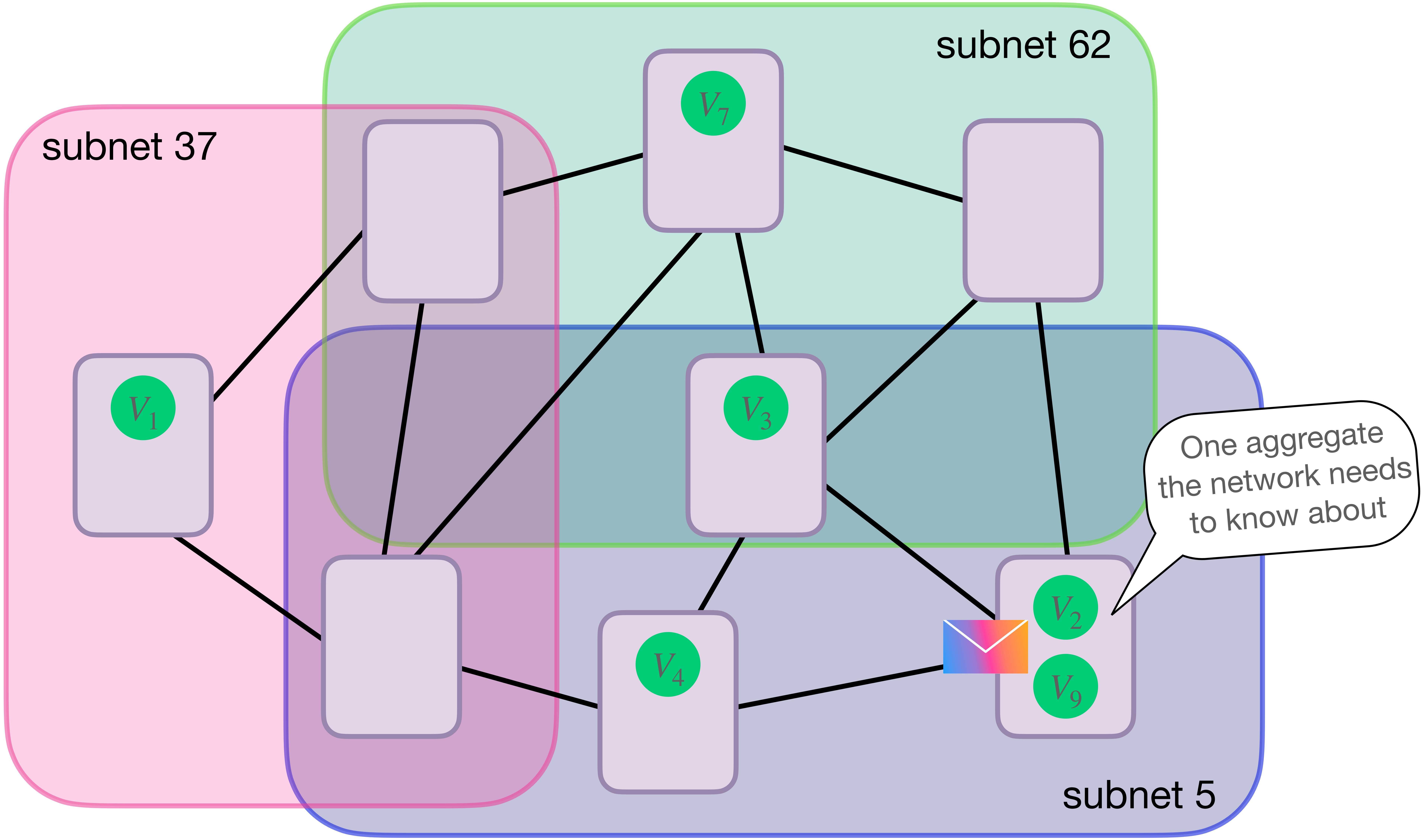

subnet 62
subnet 37
This epoch I have been assigned to subnet 5
V_7
V_1
V_3
V_4
V_2
V_9
subnet 5


subnet 62
subnet 37
Please send it to subnet 5
V_7
V_1
V_3
V_4
V_2
V_9
subnet 5

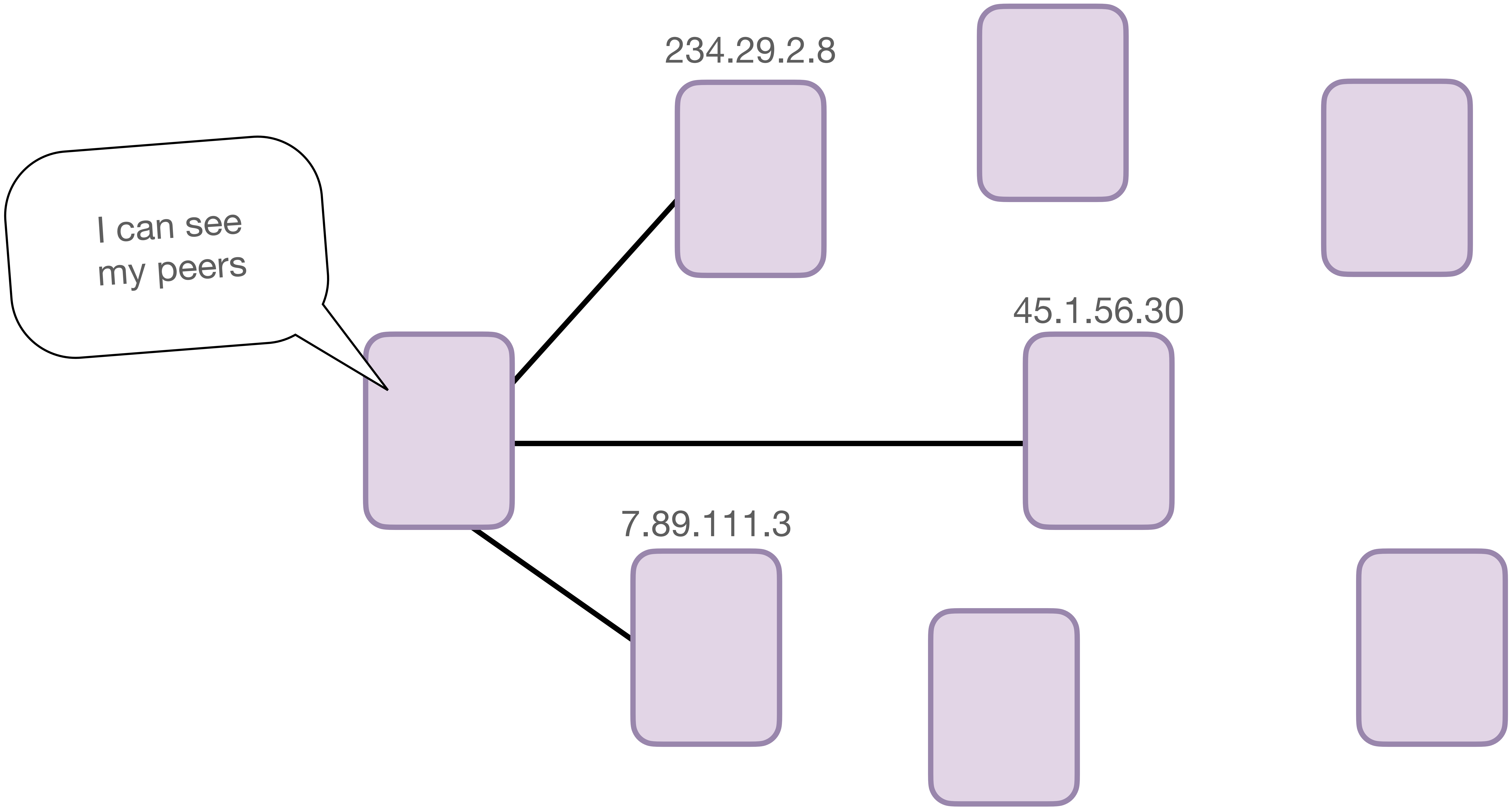

subnet 62
subnet 37
V_7
V_1
V_3
Distributing it to the subnet
V_2
V_4
V_9
subnet 5

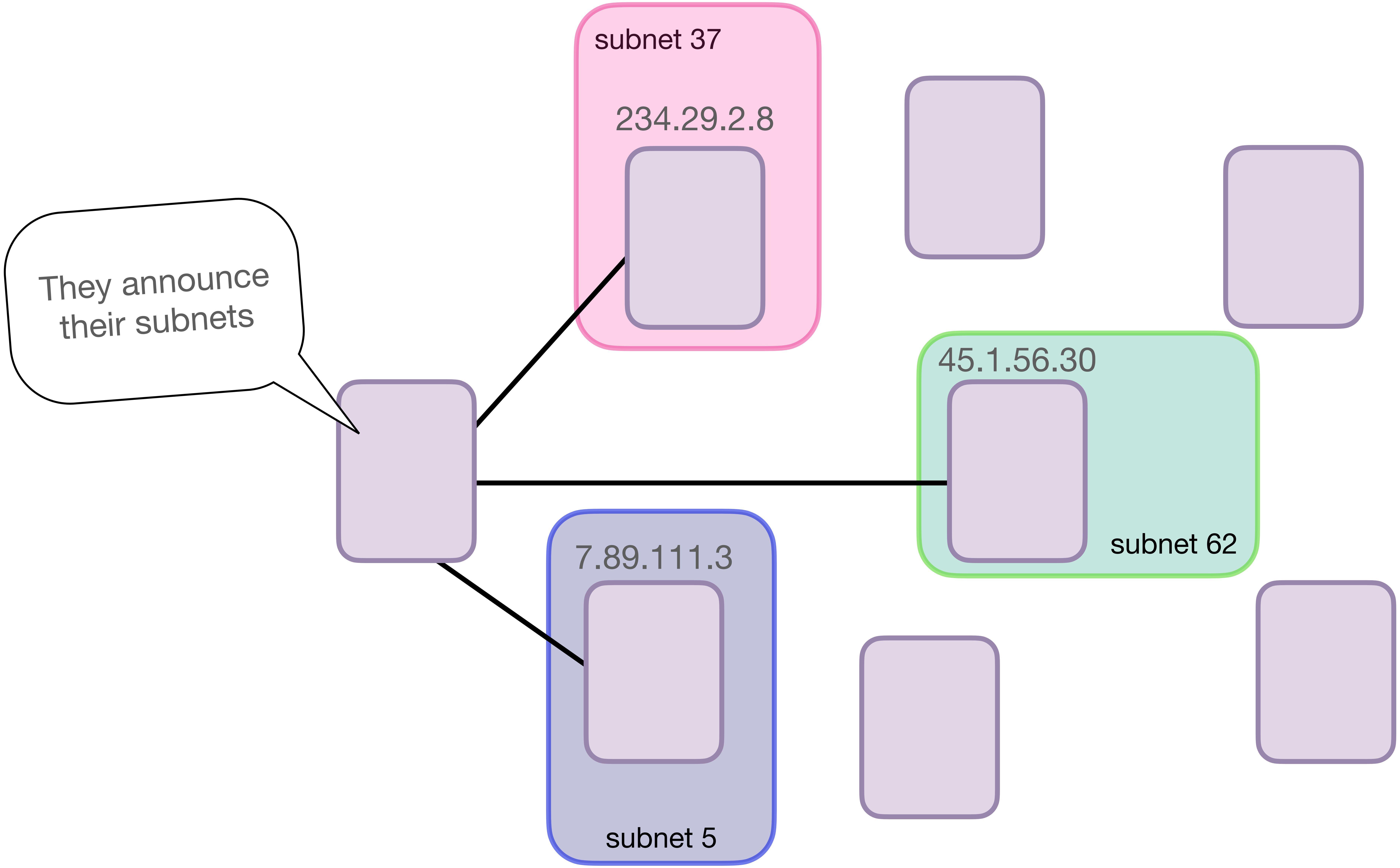

subnet 62
subnet 37
subnet 5
V_7
V_1
V_3
V_4
V_2
V_9
Distributing it to the subnet

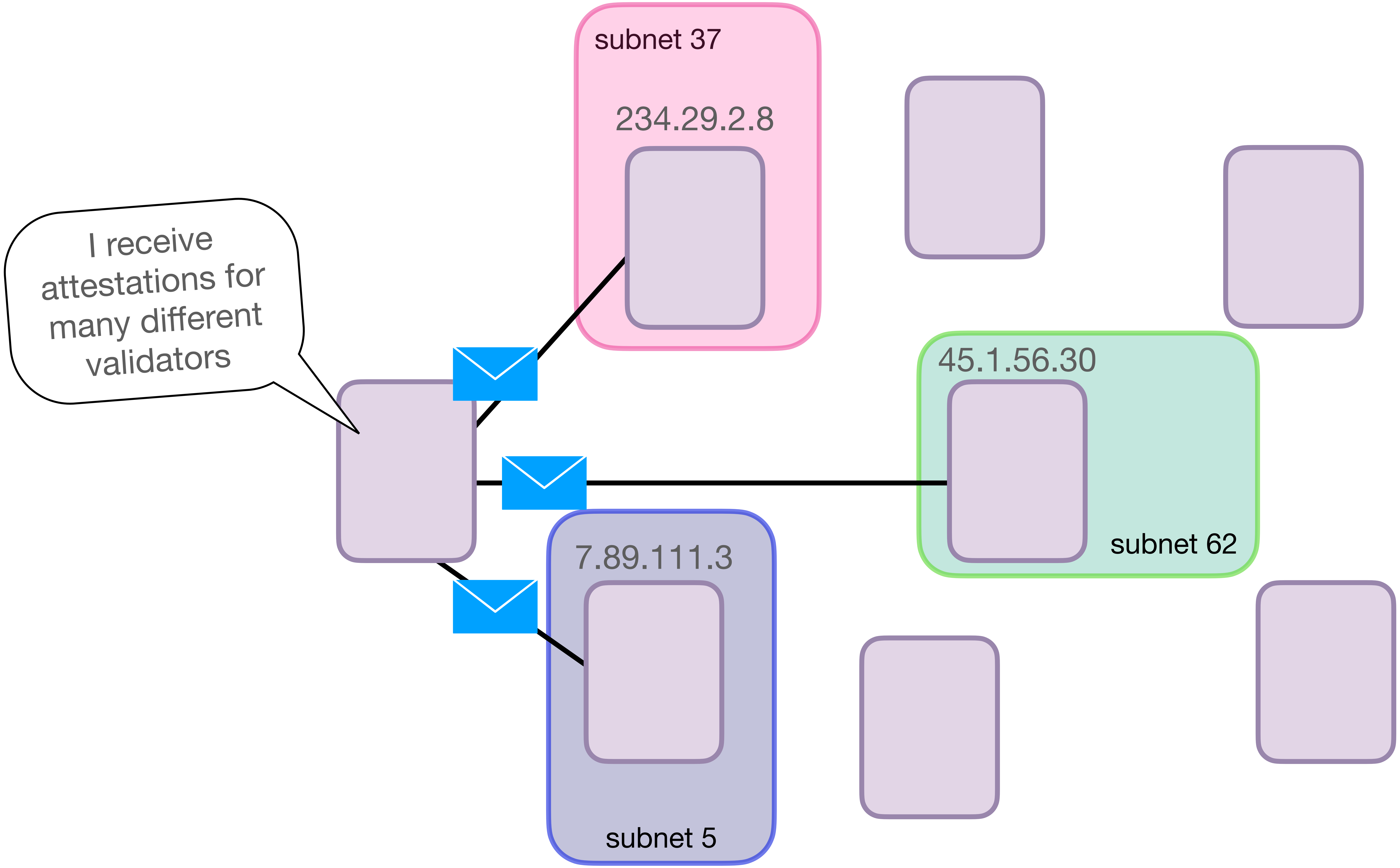

subnet 62
subnet 37
subnet 5
V_7
V_1
V_3
V_4
V_2
V_9



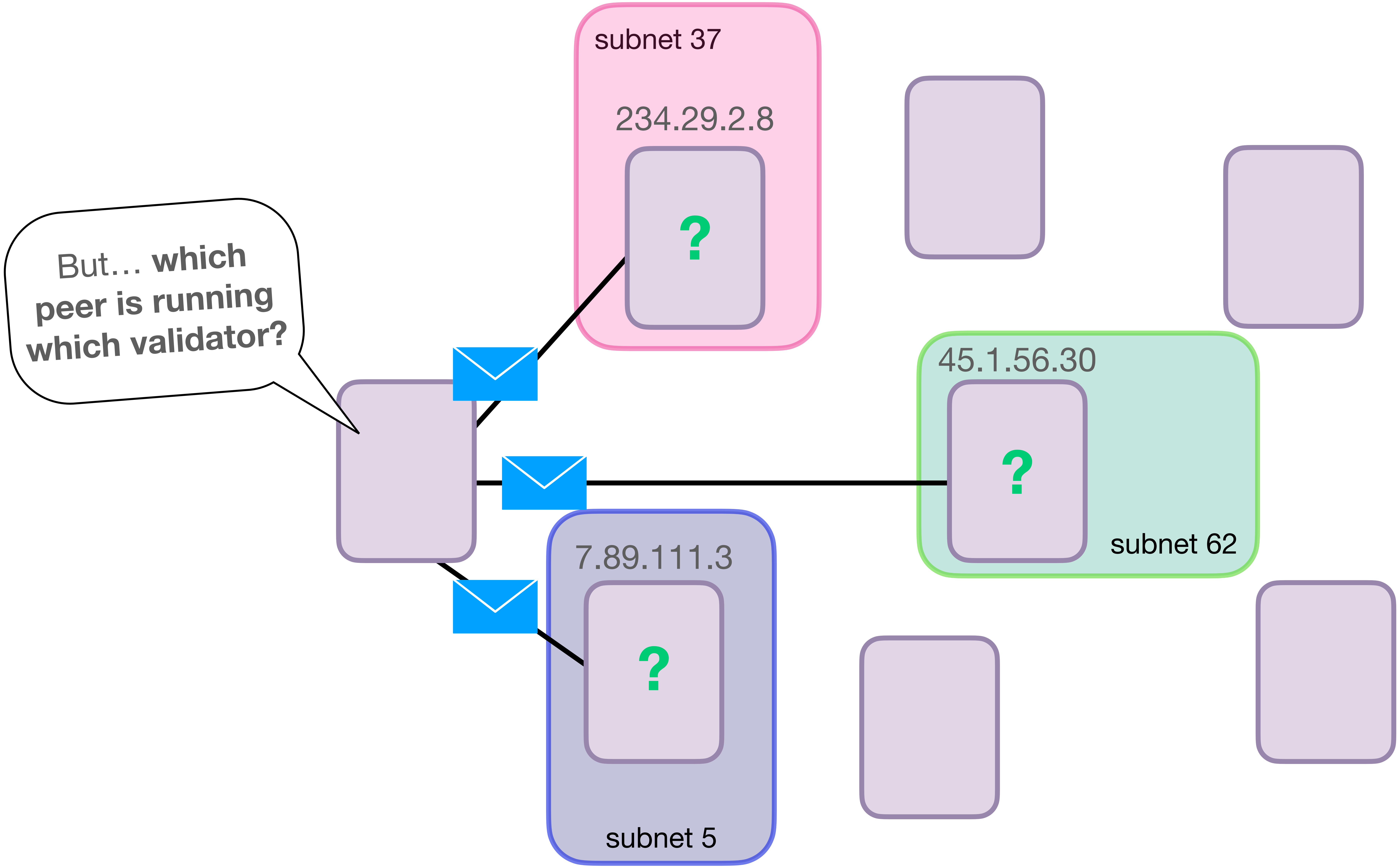
Do we give up privacy as a tradeoff for lower network load?


I can see my peers
234.29.2.8
45.1.56.30
7.89.111.3

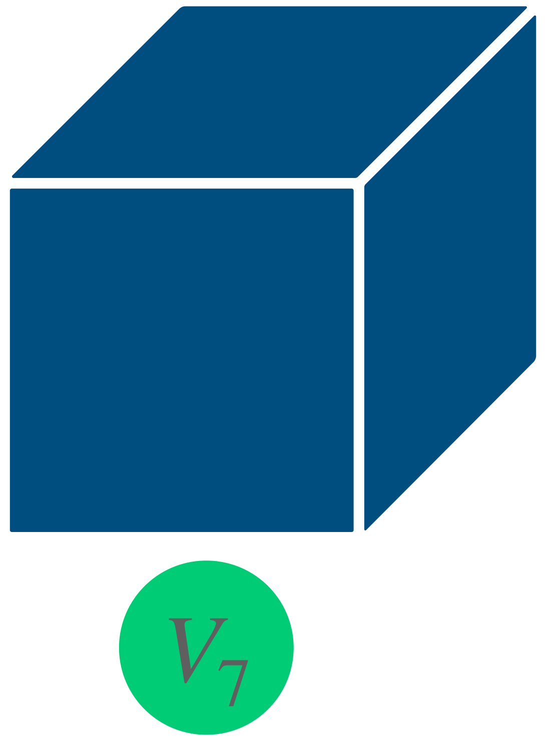

They announce their subnets
subnet 37
234.29.2.8
45.1.56.30
subnet 62
7.89.111.3
subnet 5

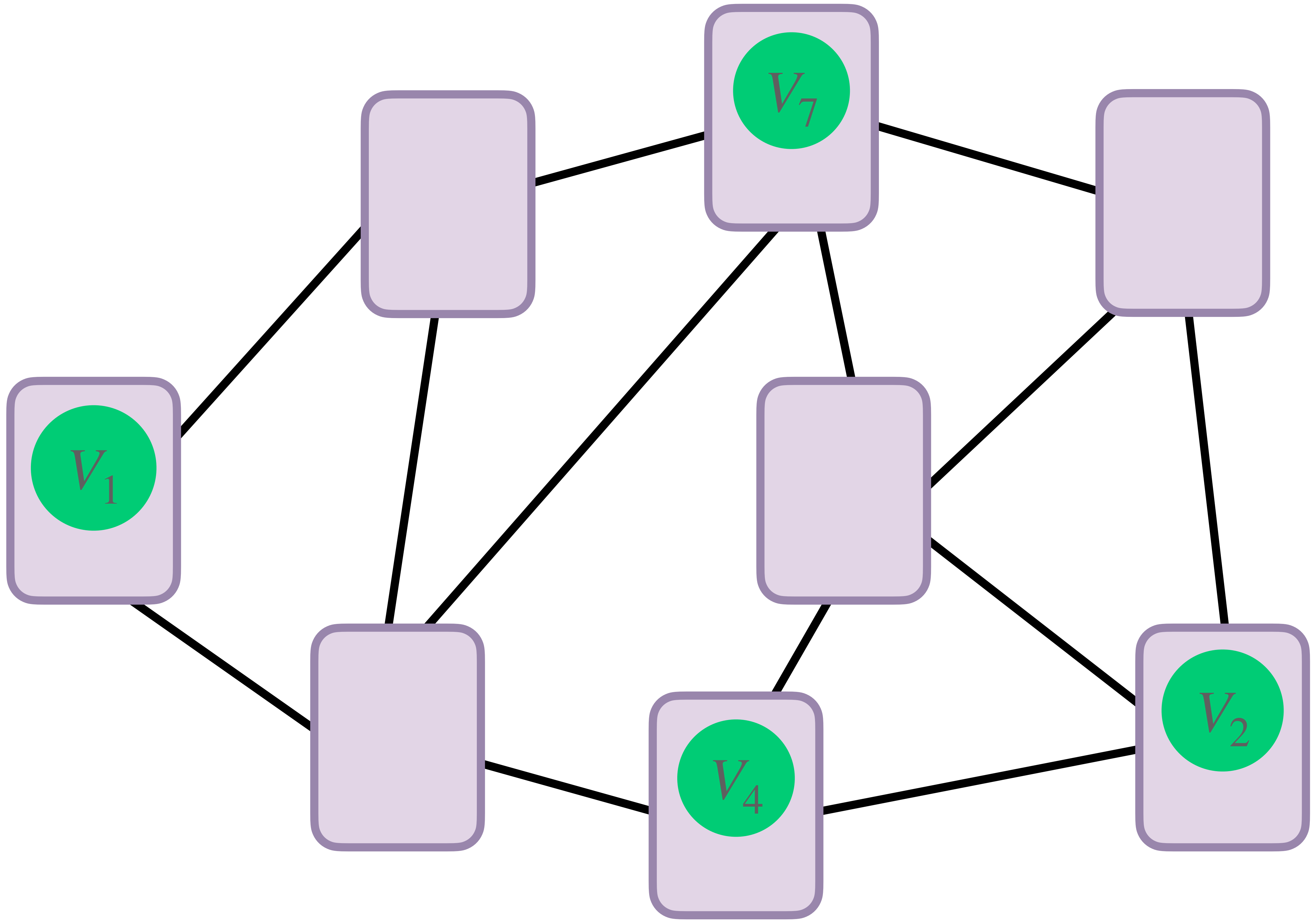


I receive attestations for many different validators
subnet 37
234.29.2.8
45.1.56.30
subnet 62
7.89.111.3
subnet 5

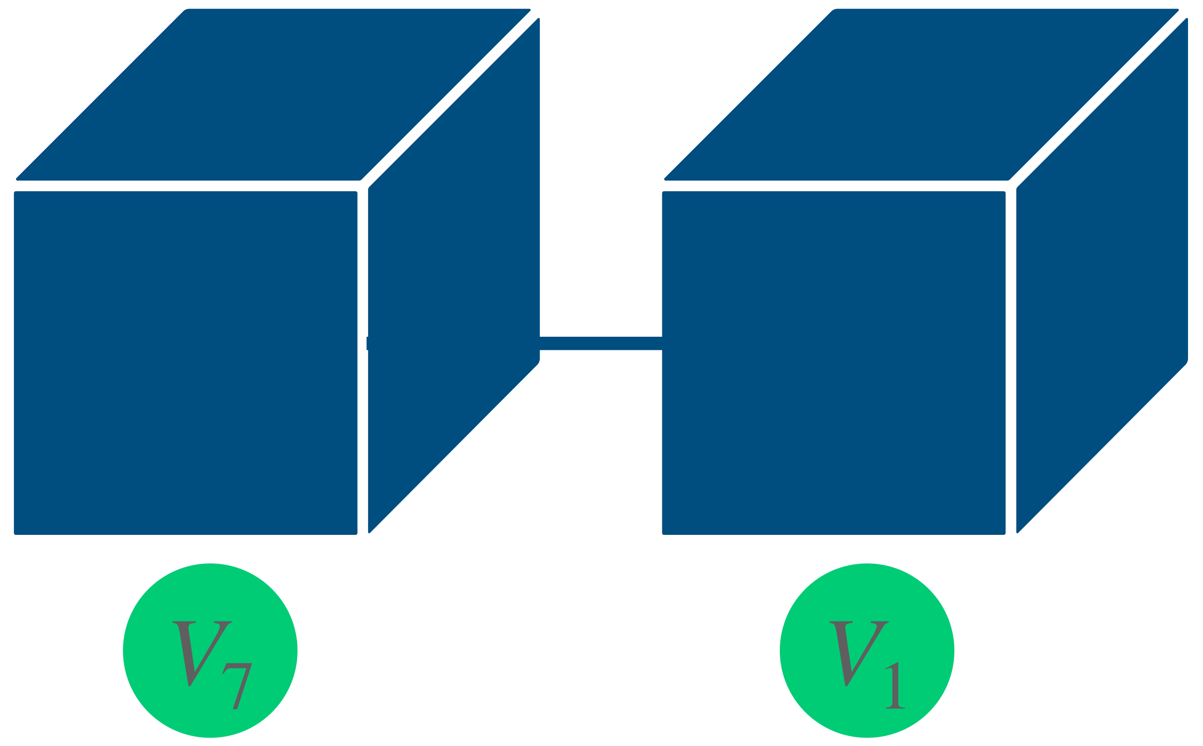

But… which peer is running which validator?
subnet 37
234.29.2.8
?
45.1.56.30
?
subnet 62
7.89.111.3
?
subnet 5

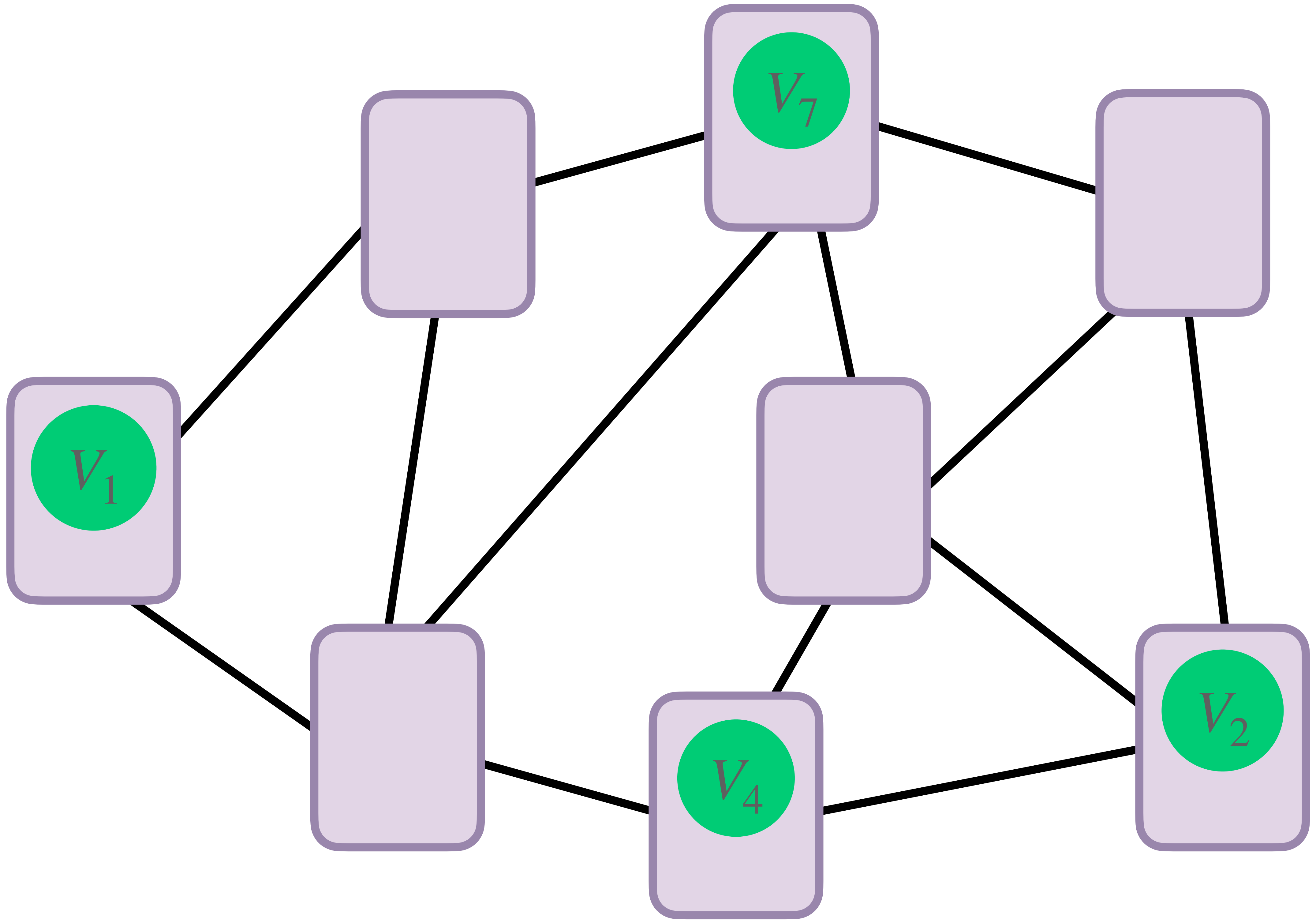
Why does anonymity matter?



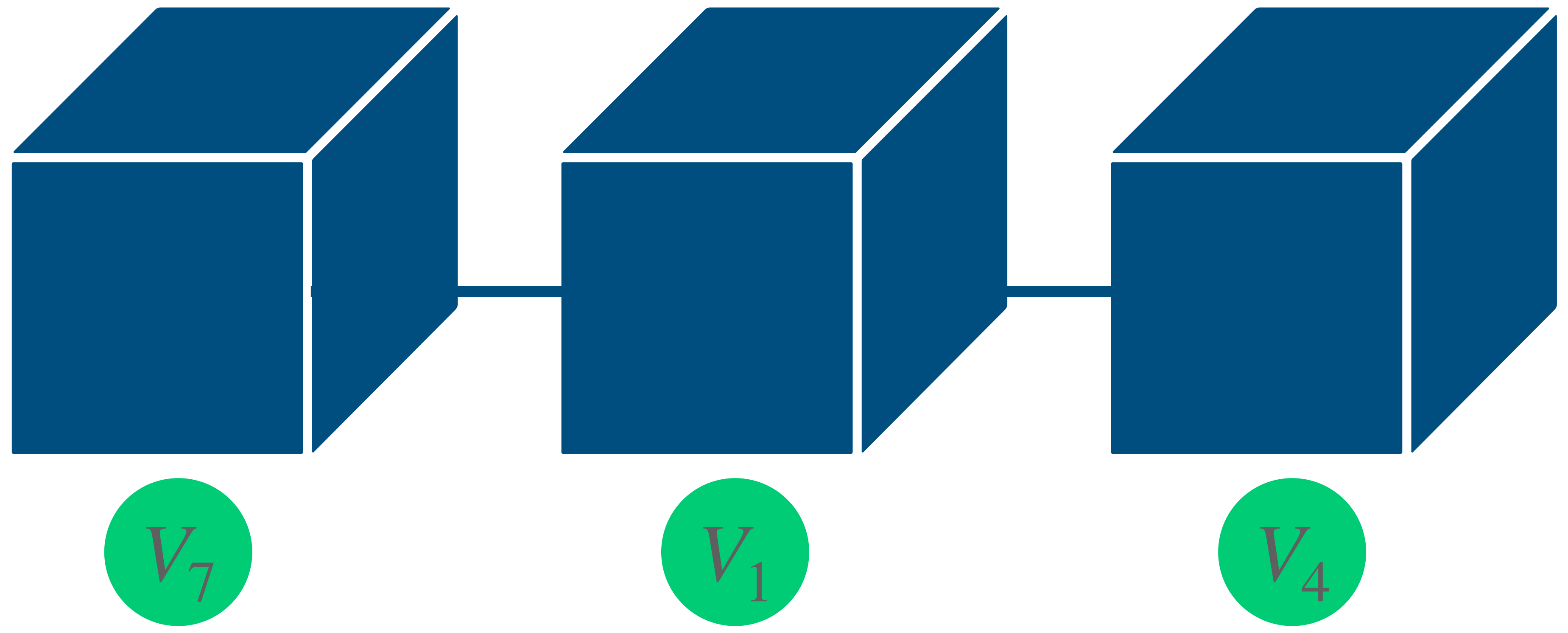


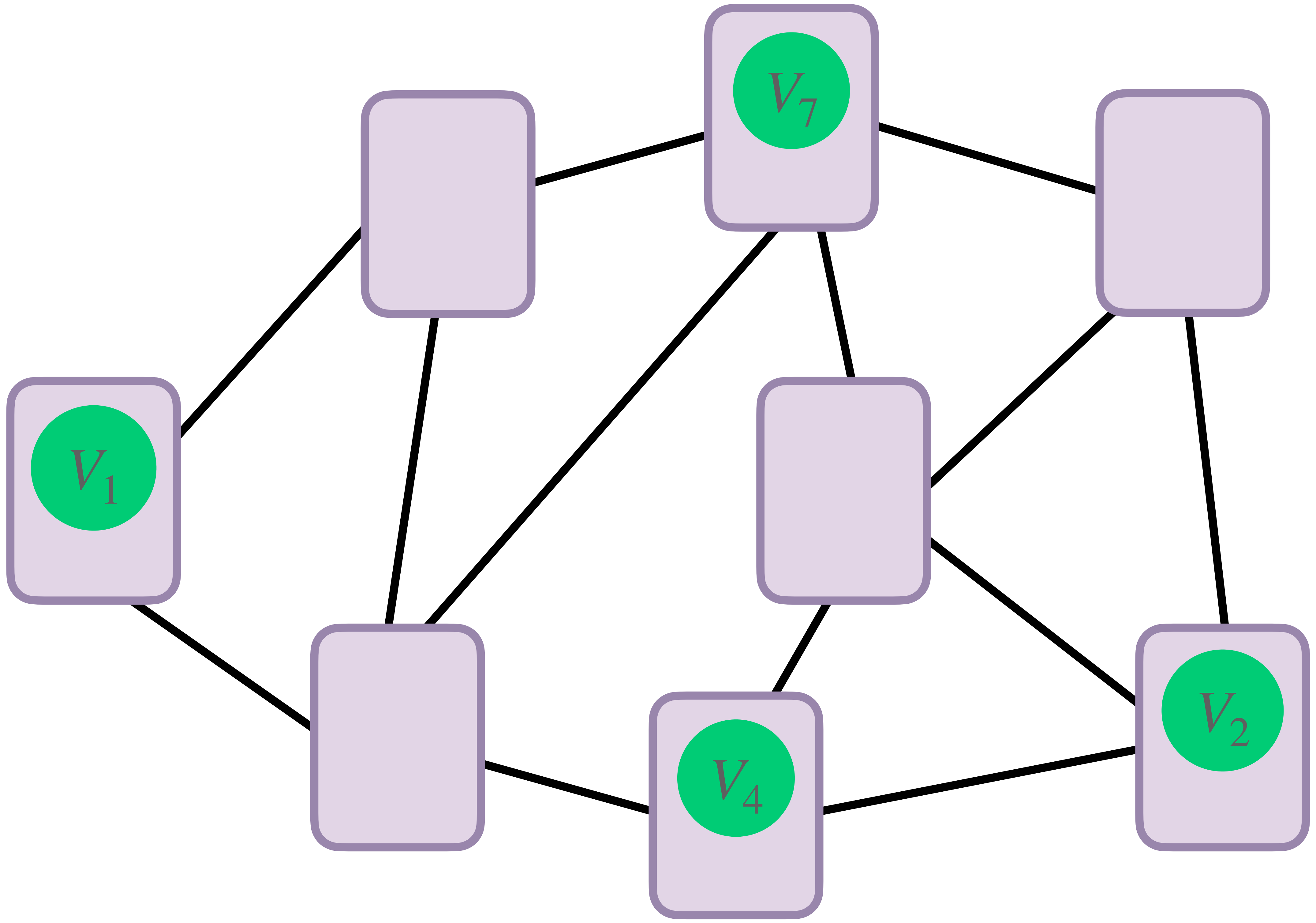
Why does anonymity matter?



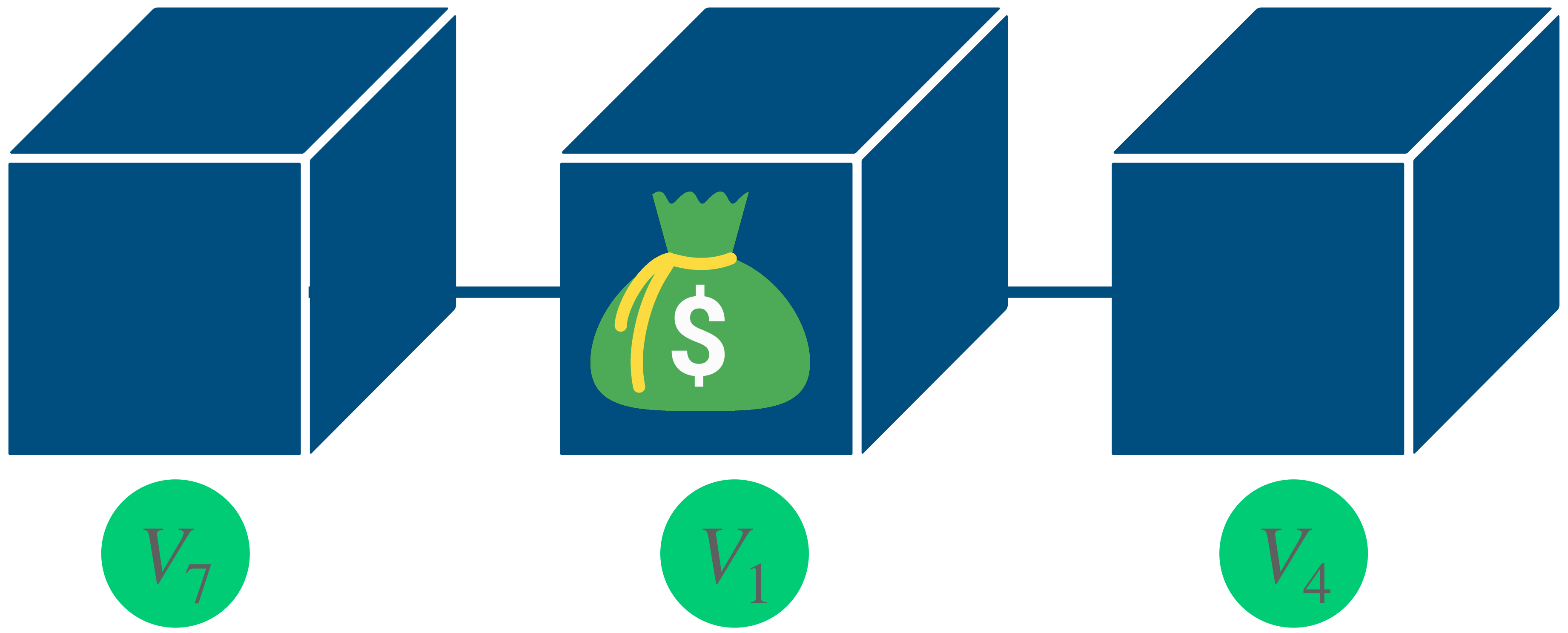


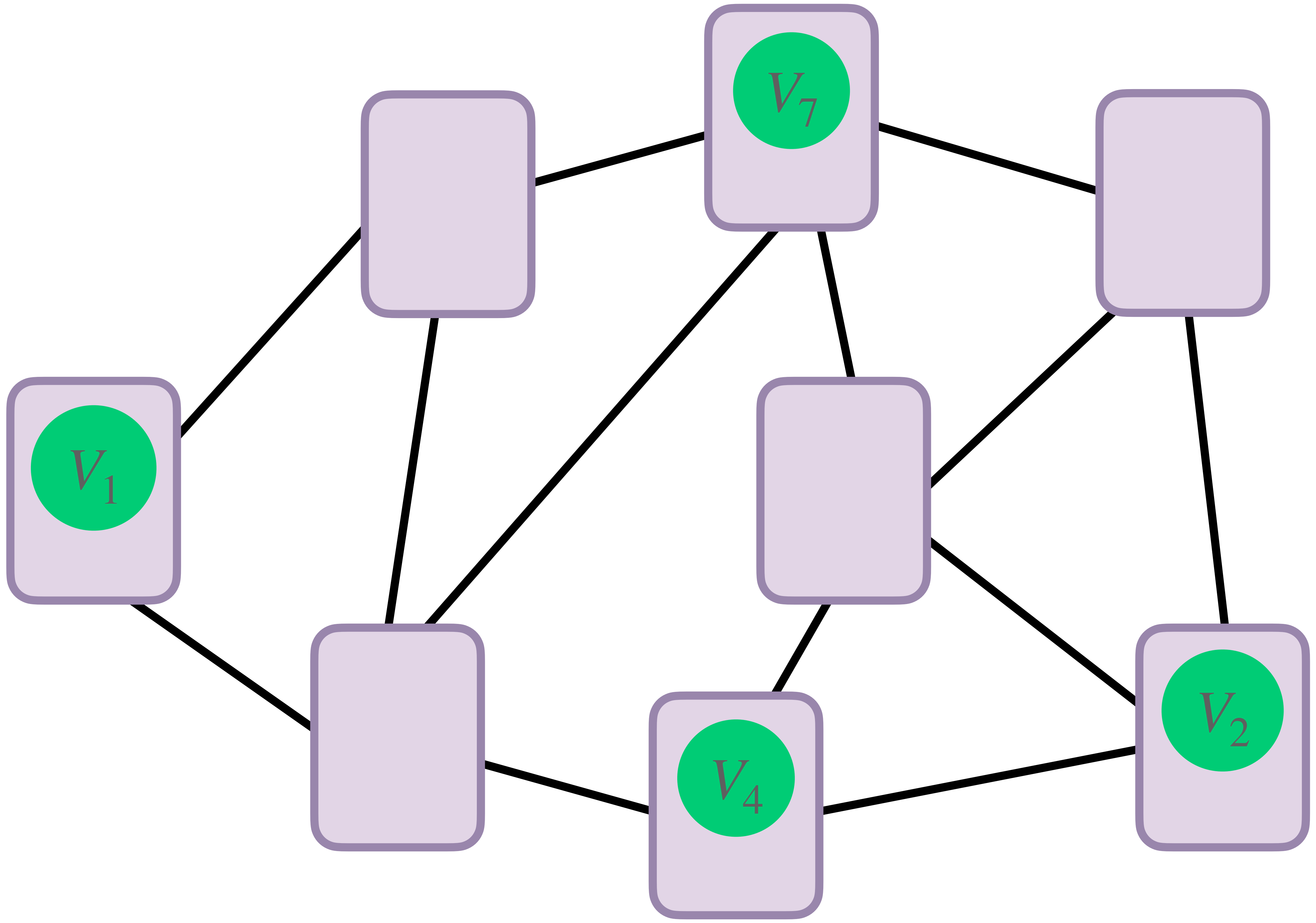
Why does anonymity matter?



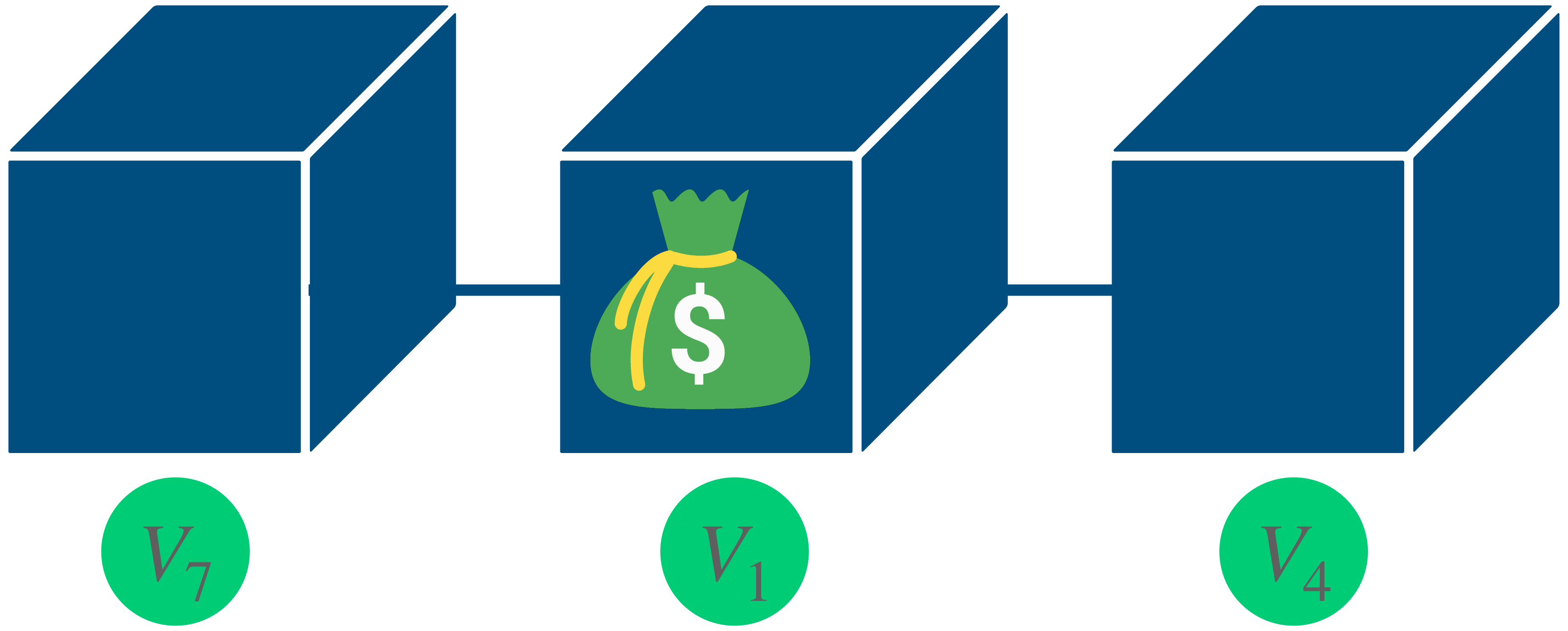


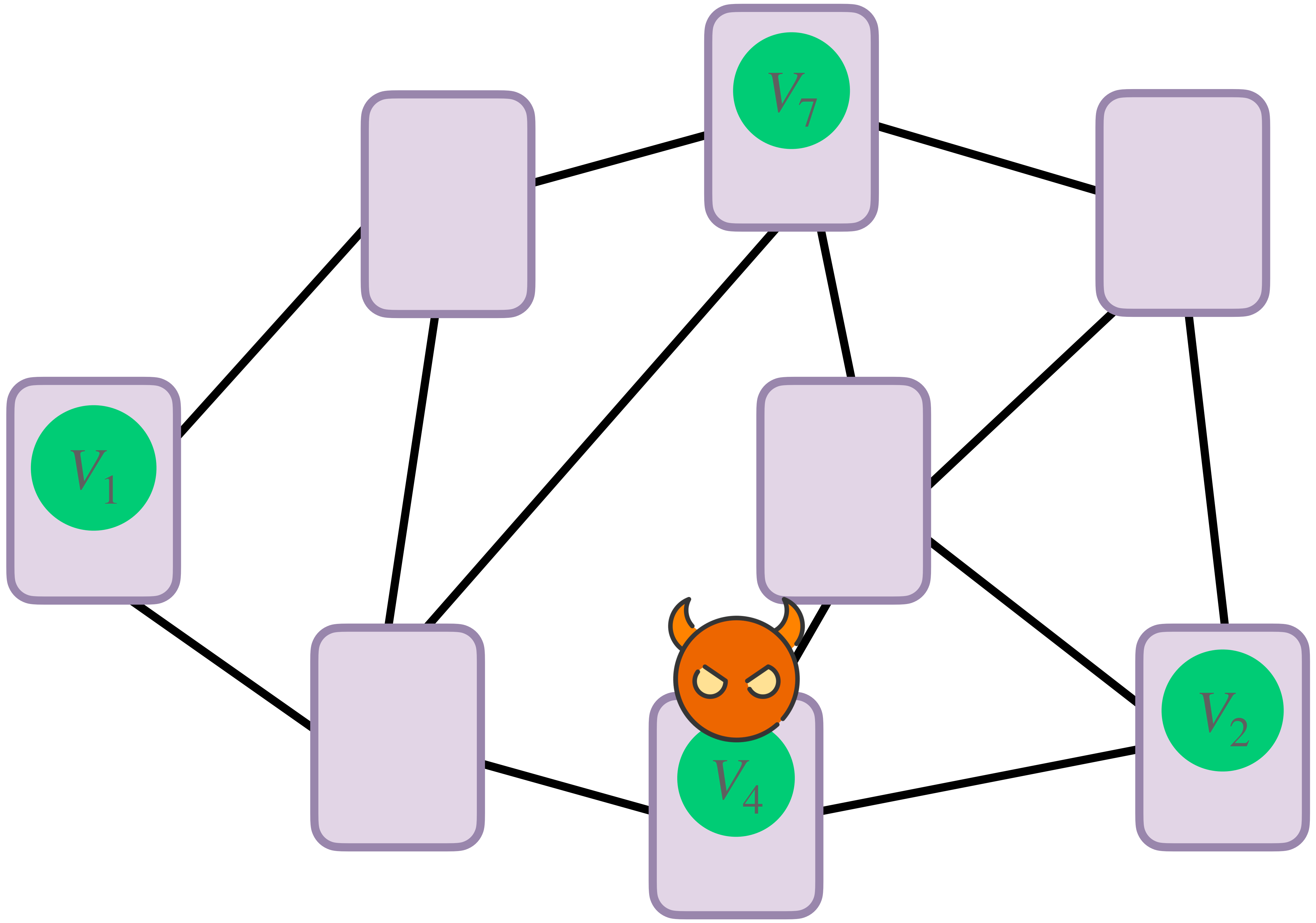
Why does anonymity matter?





Why does anonymity matter?





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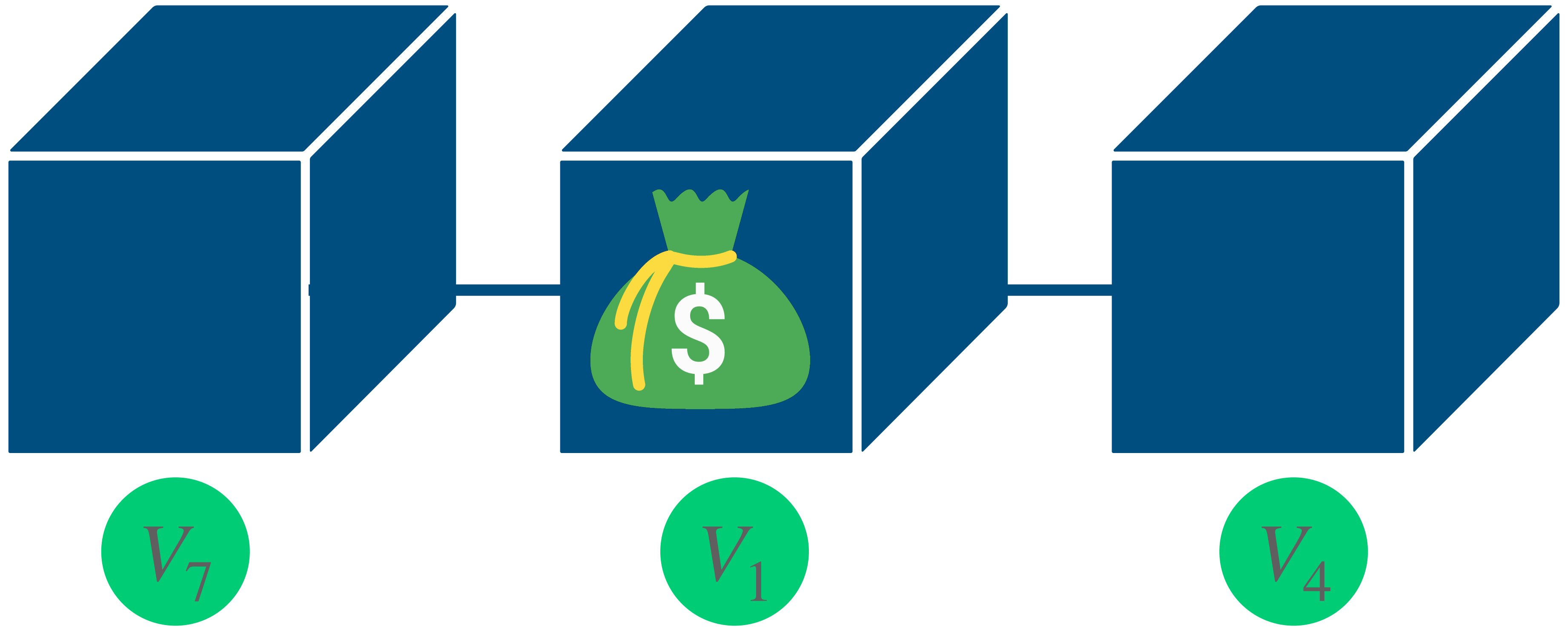
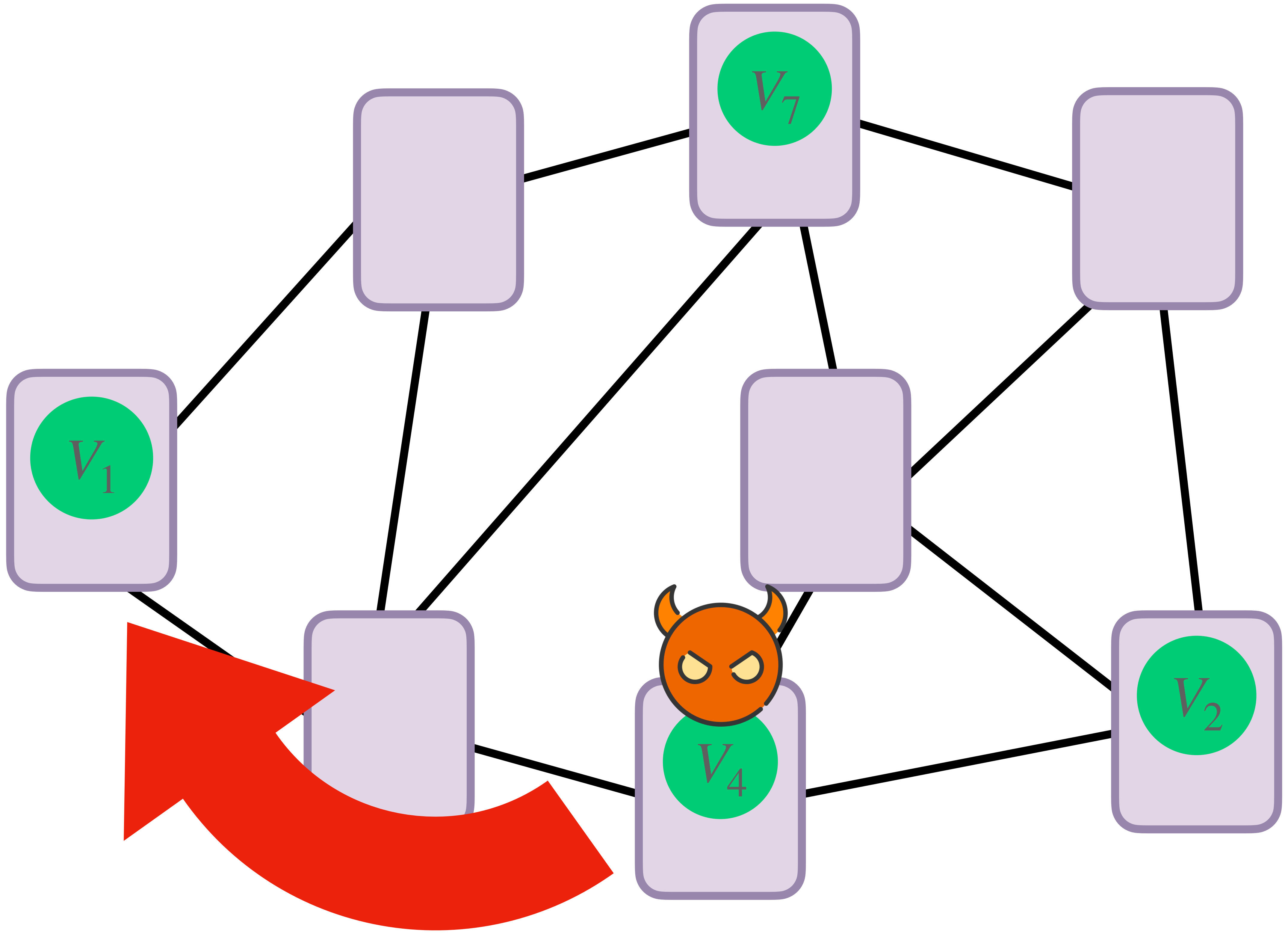
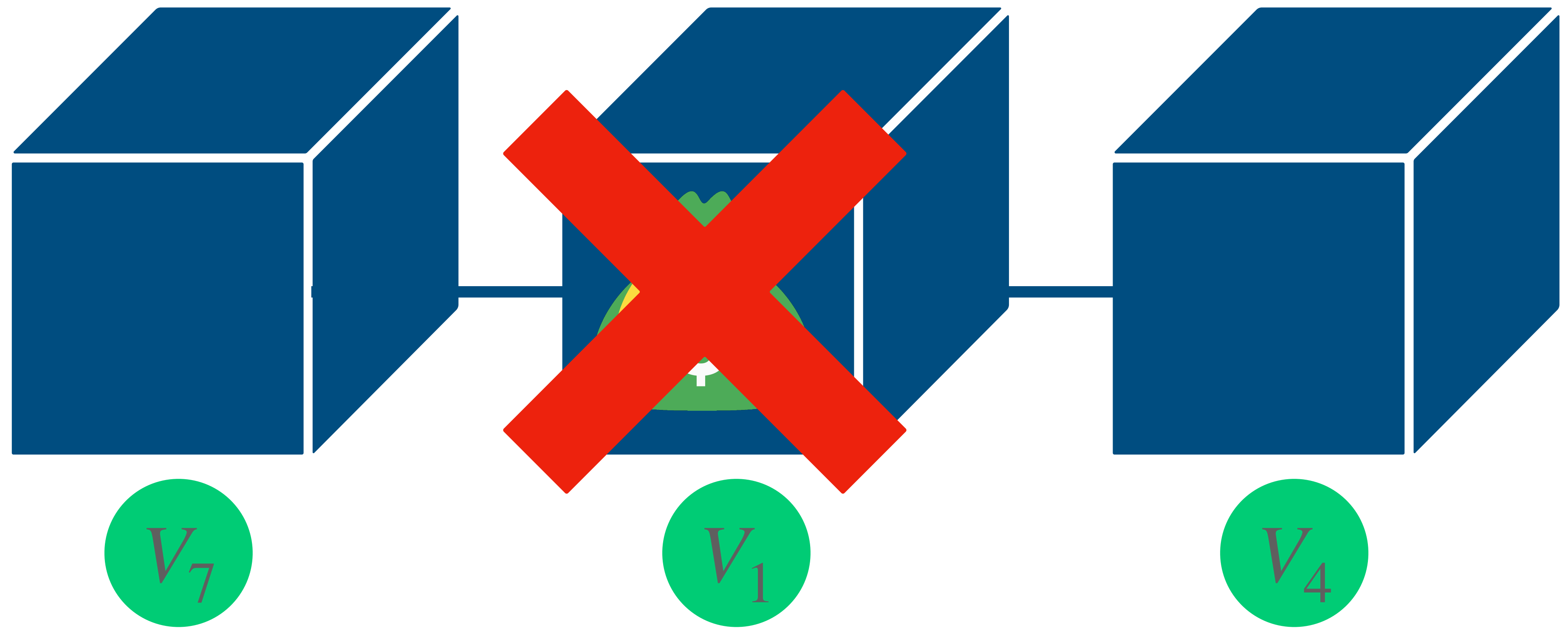
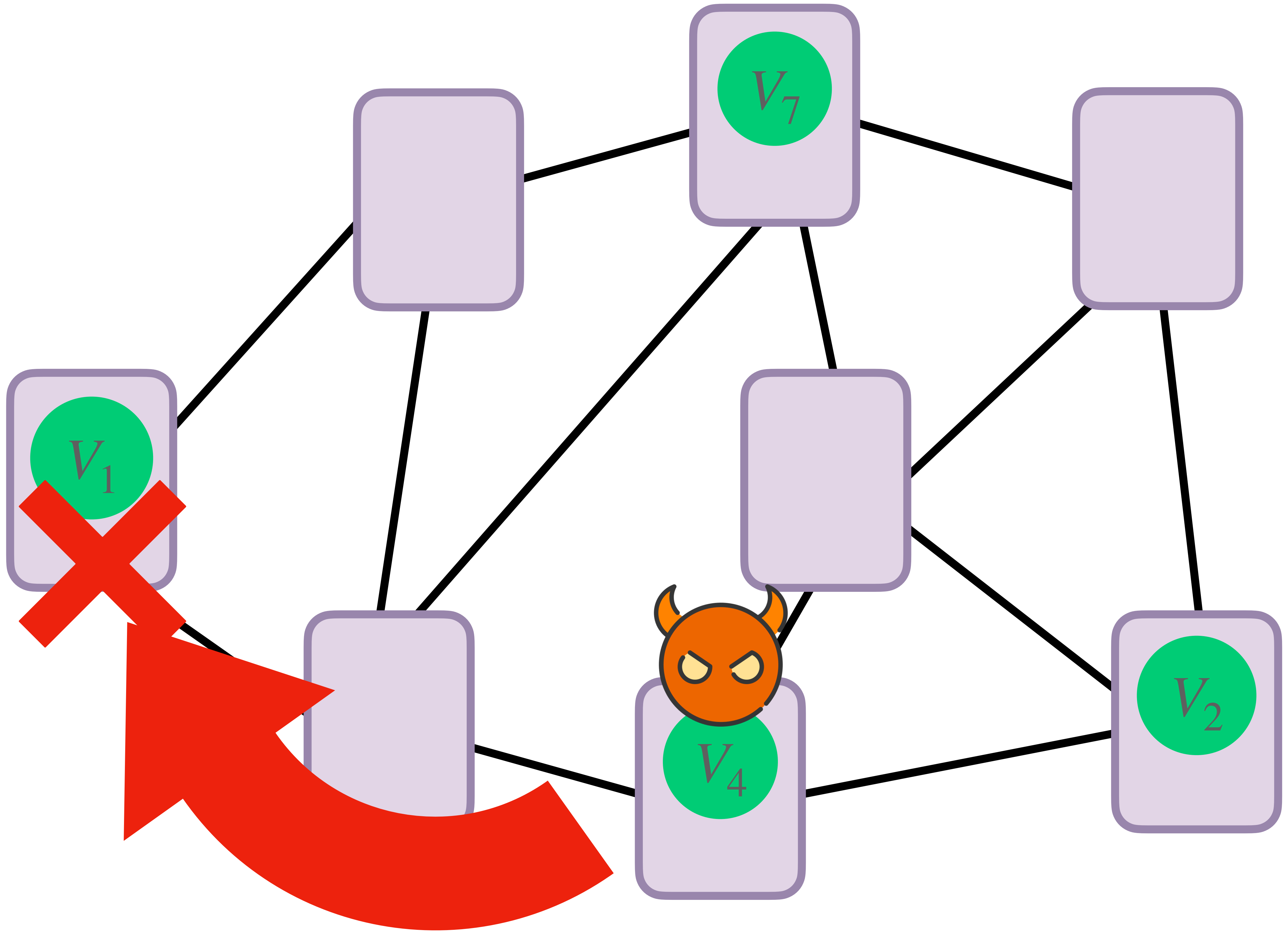


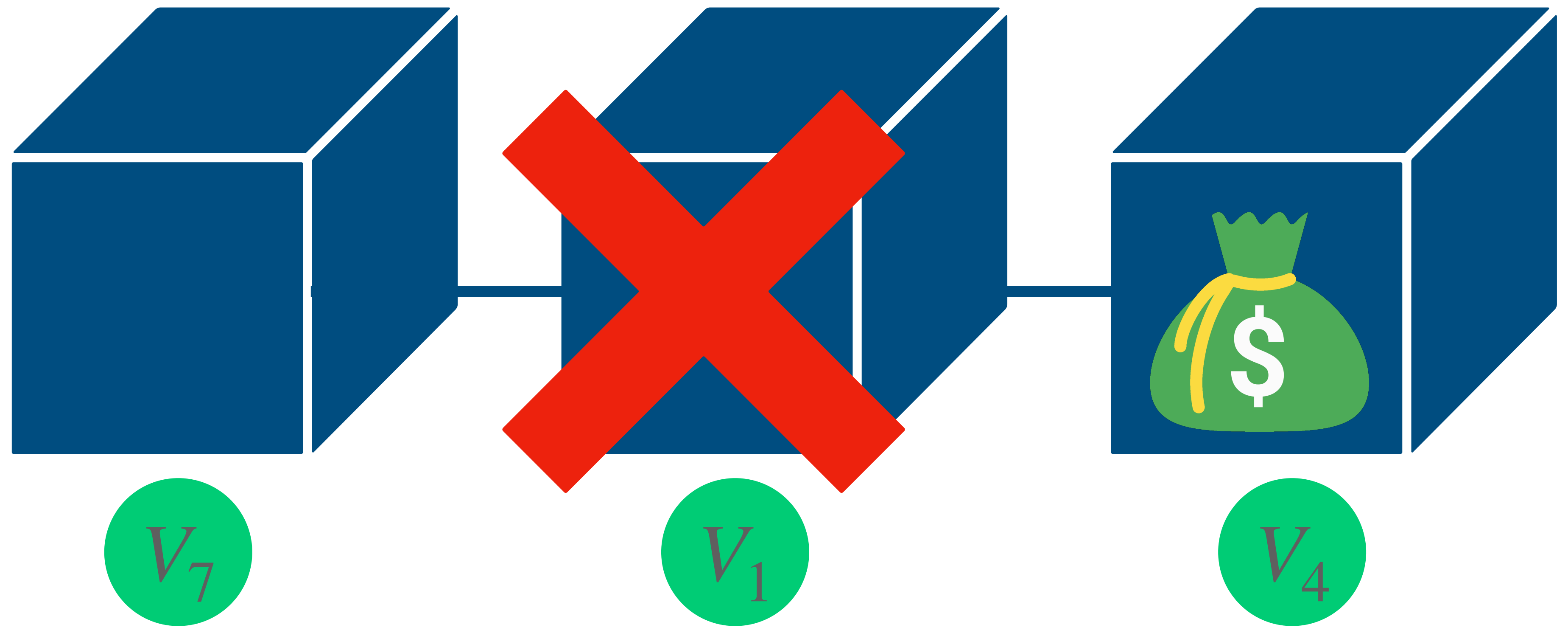


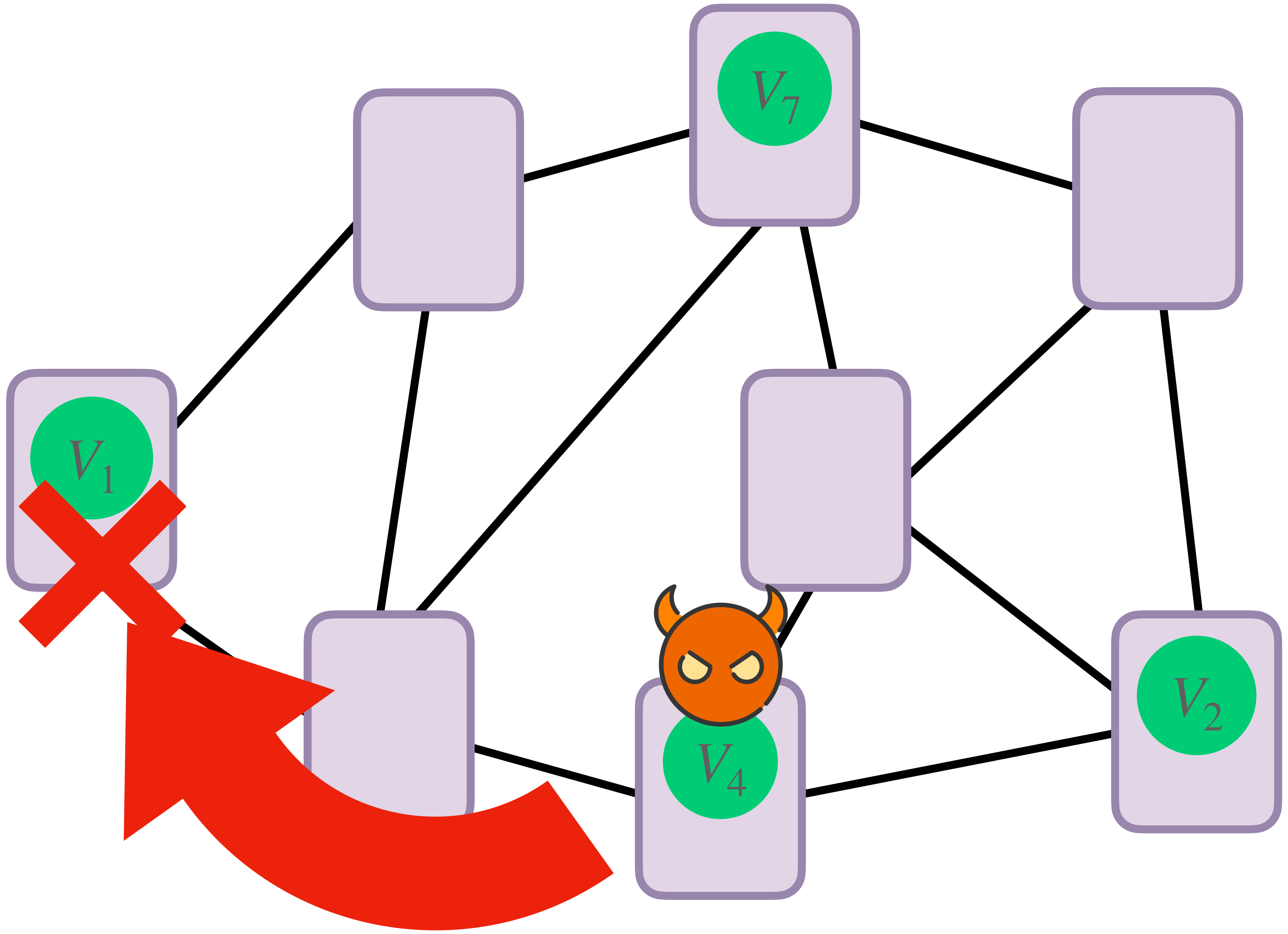
Why does anonymity matter?





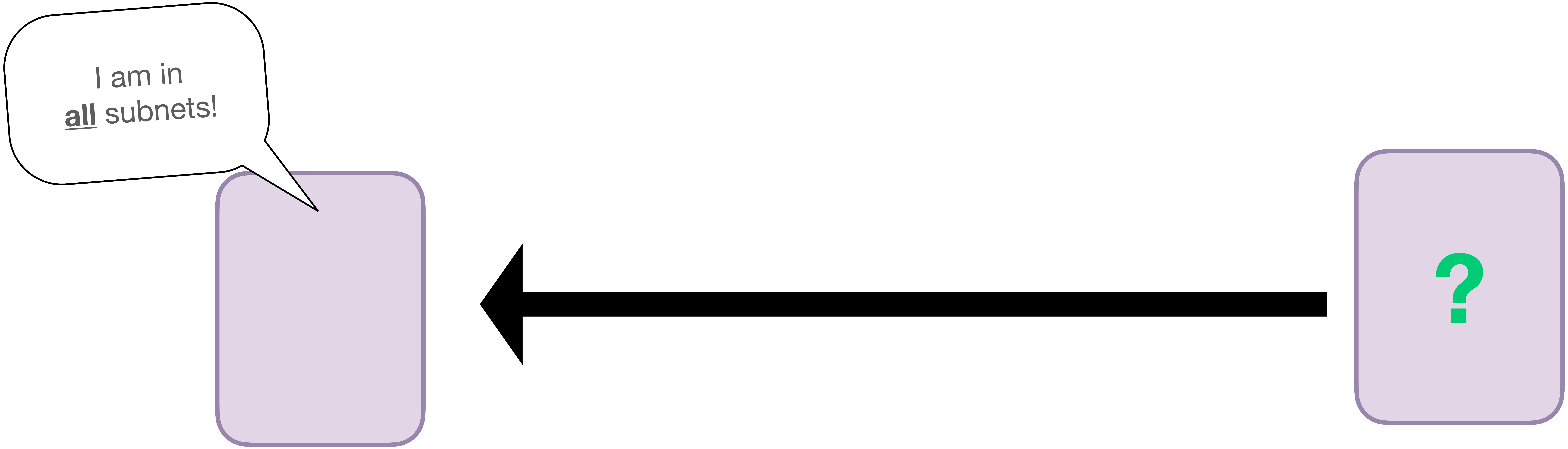
Why does anonymity matter?



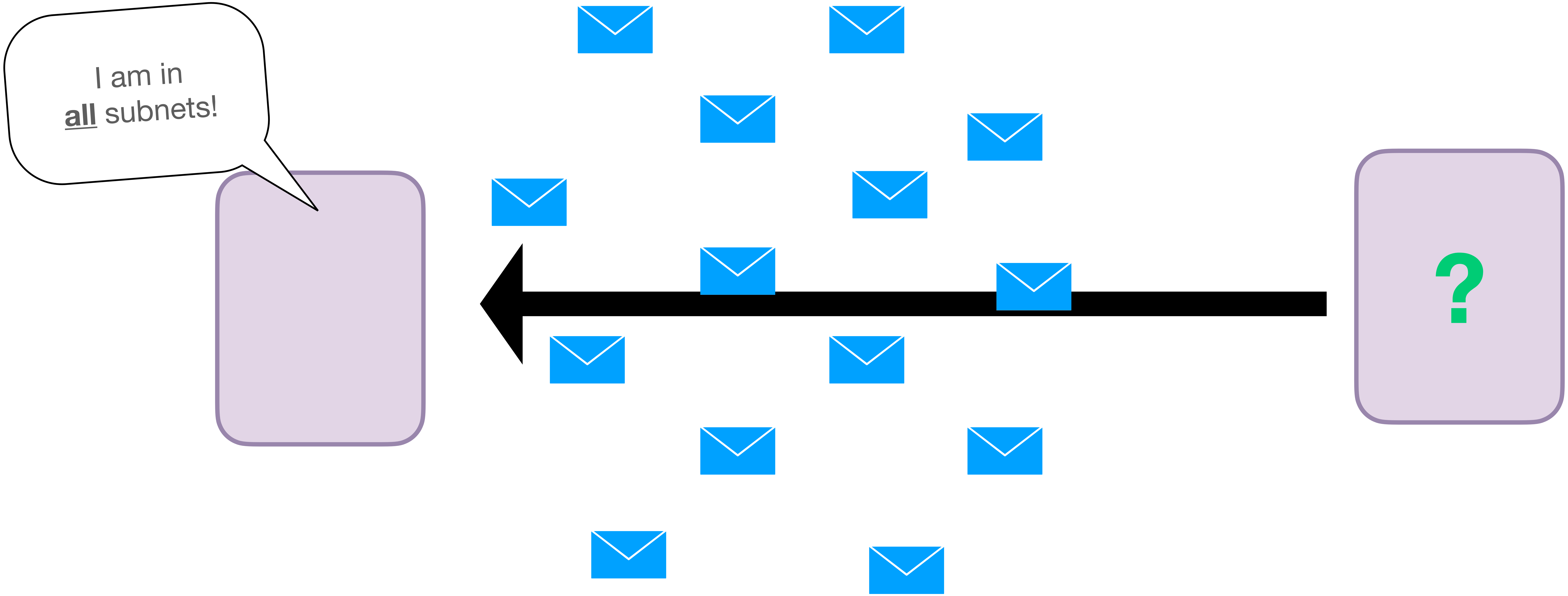


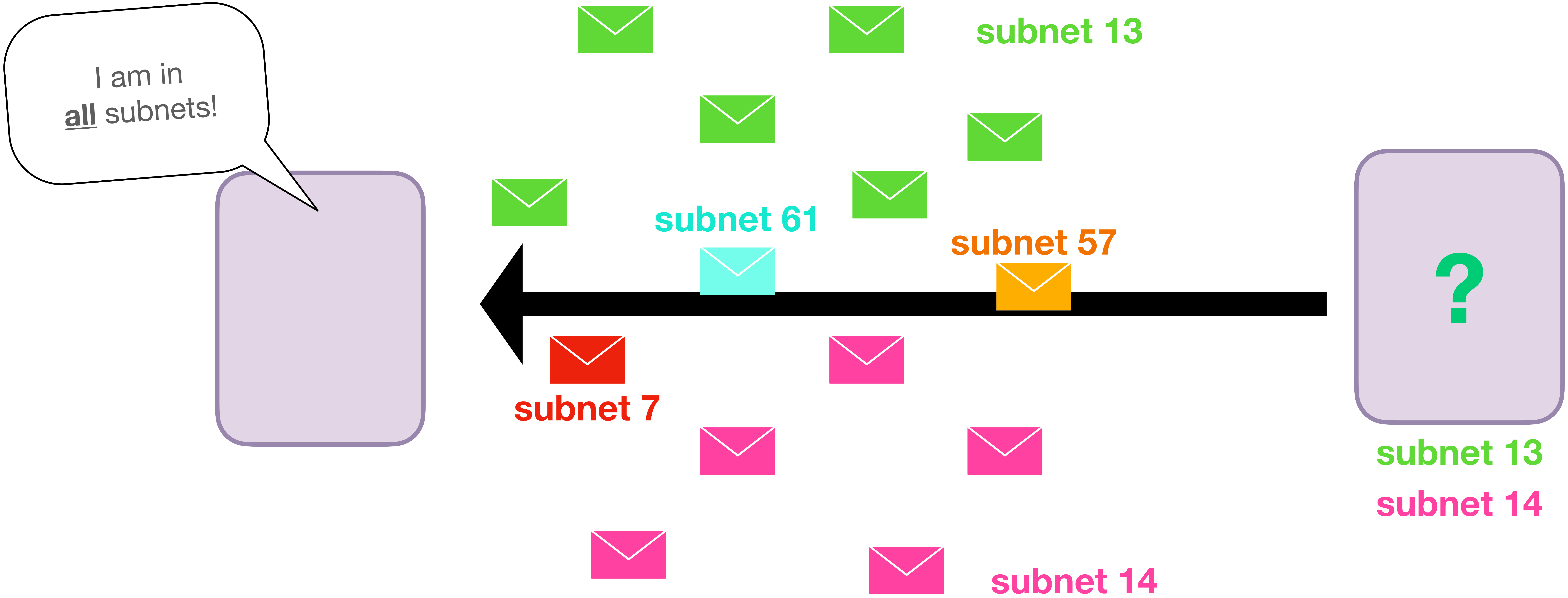
Implications of de-anonymizing validators:

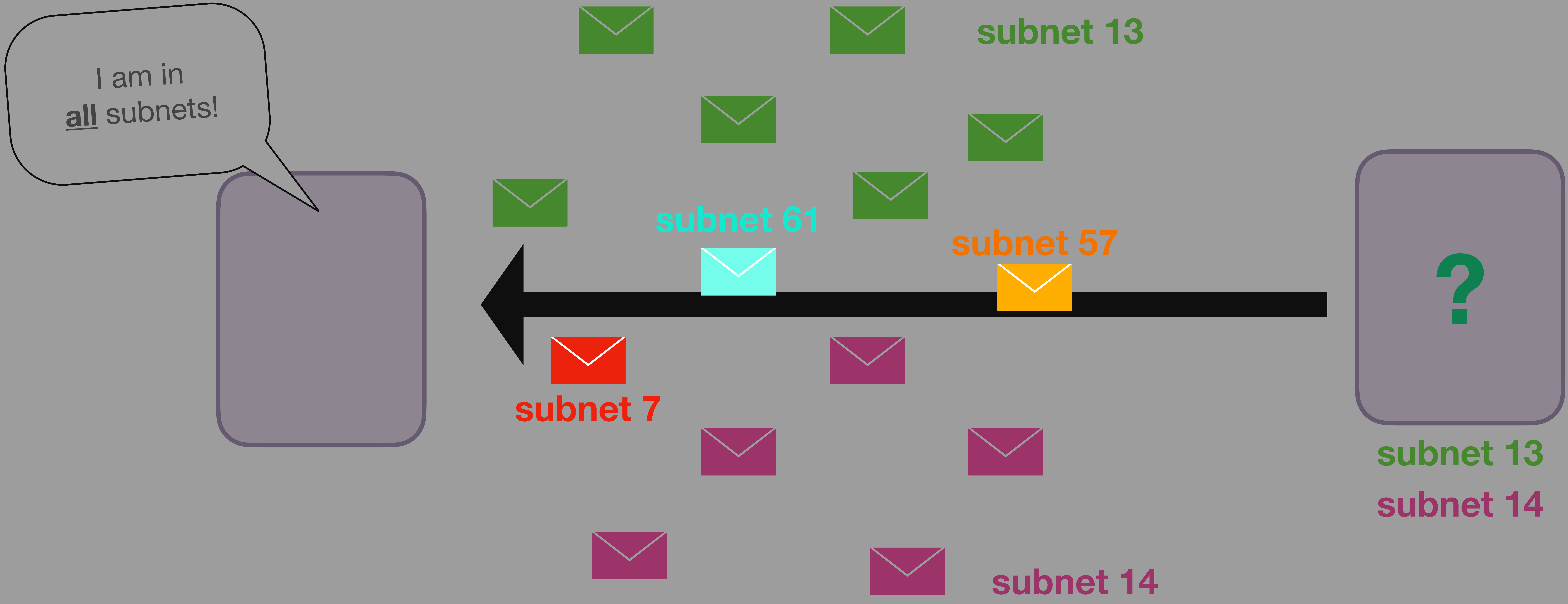
De-anonymization Methodology

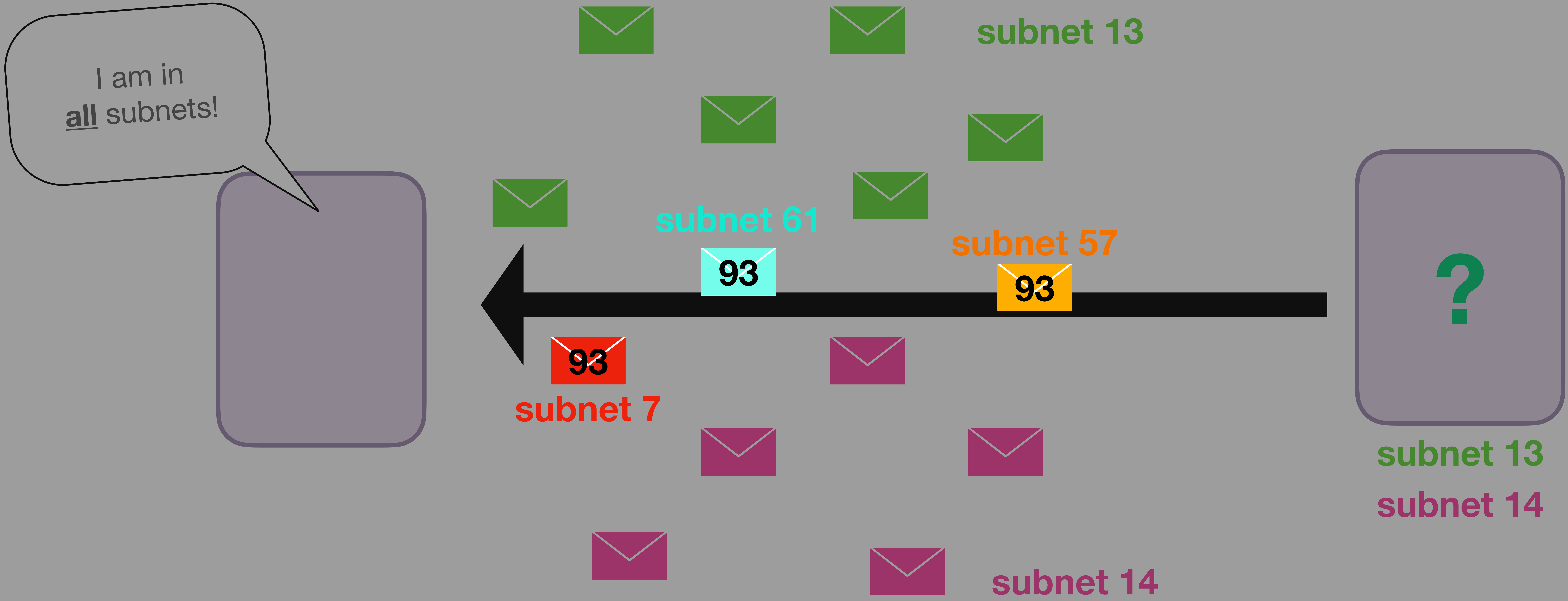


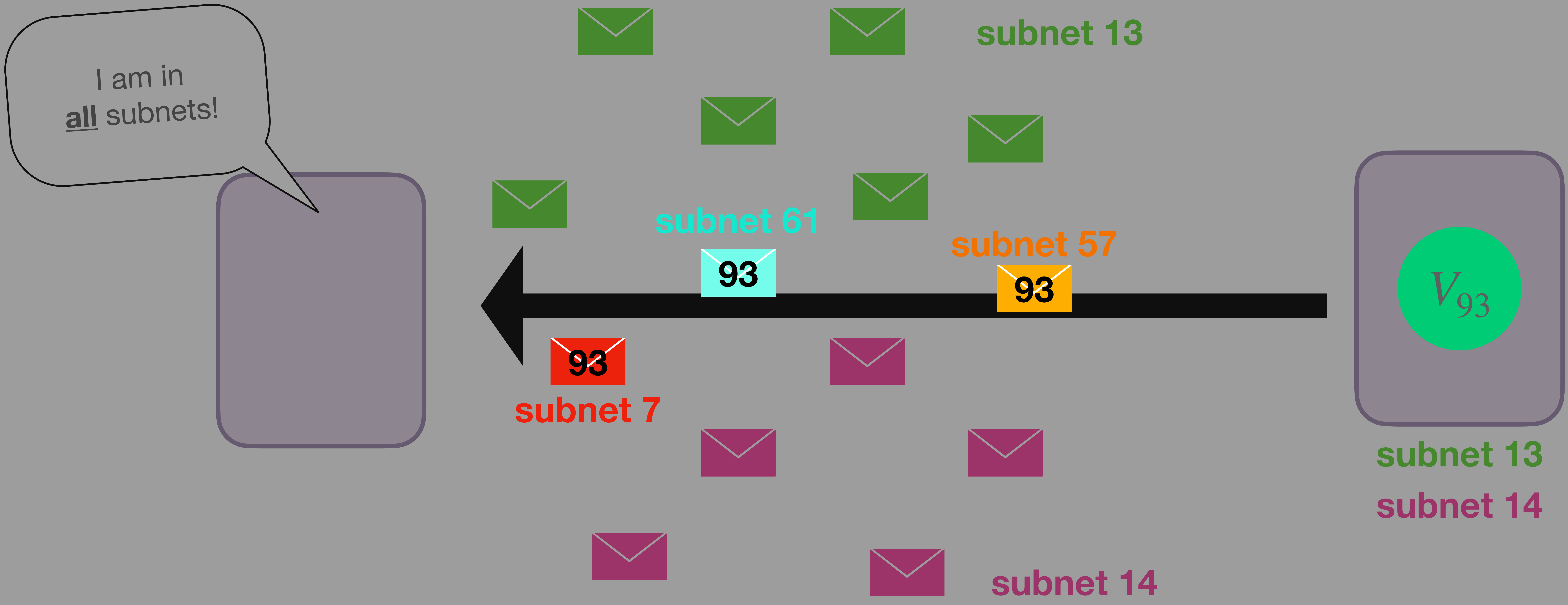
I am in
all subnets!

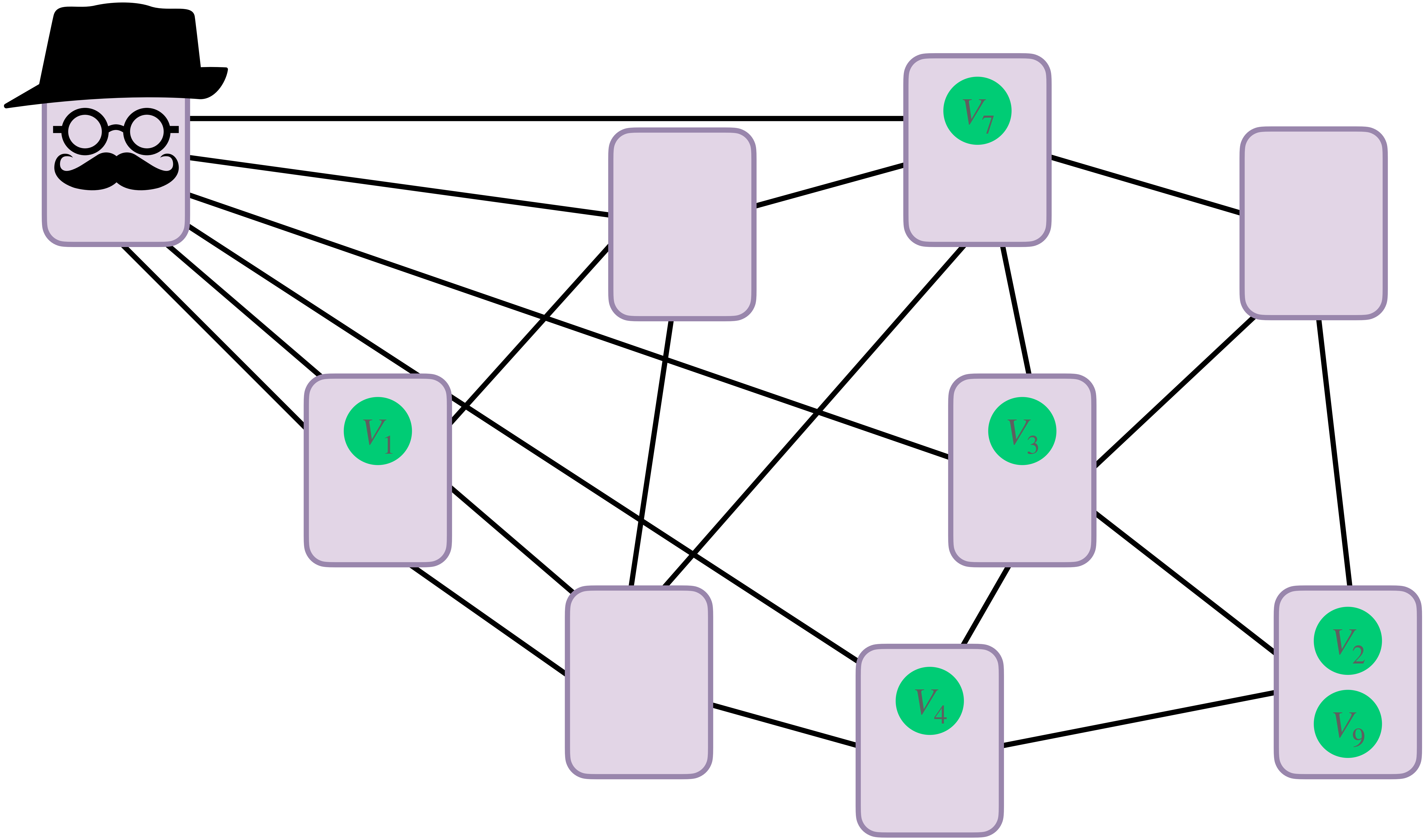

I am in
all subnets!
?

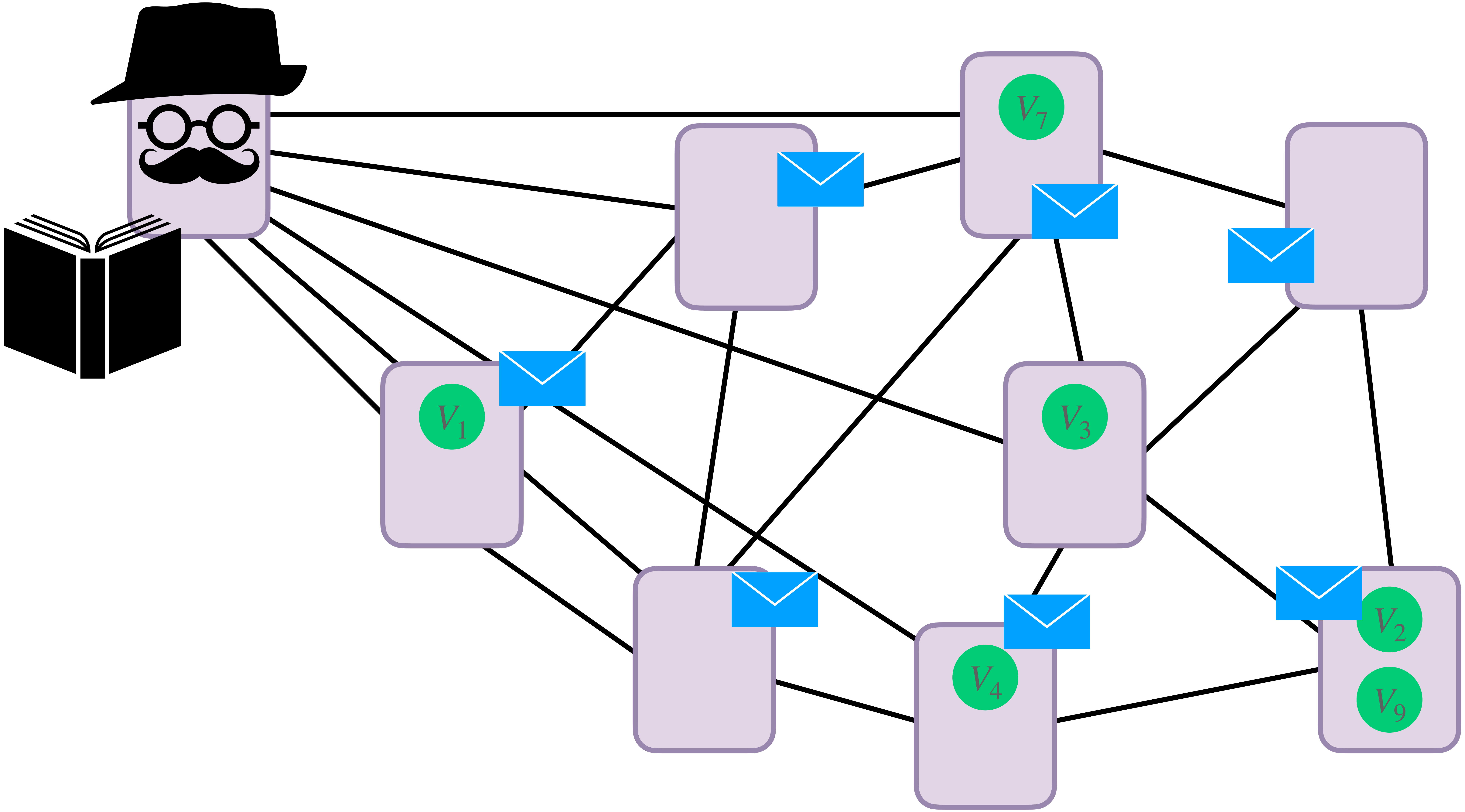

I am in
all subnets!
subnet 13
subnet 61
subnet 57
subnet 7
?
subnet 13
subnet 14
subnet 14

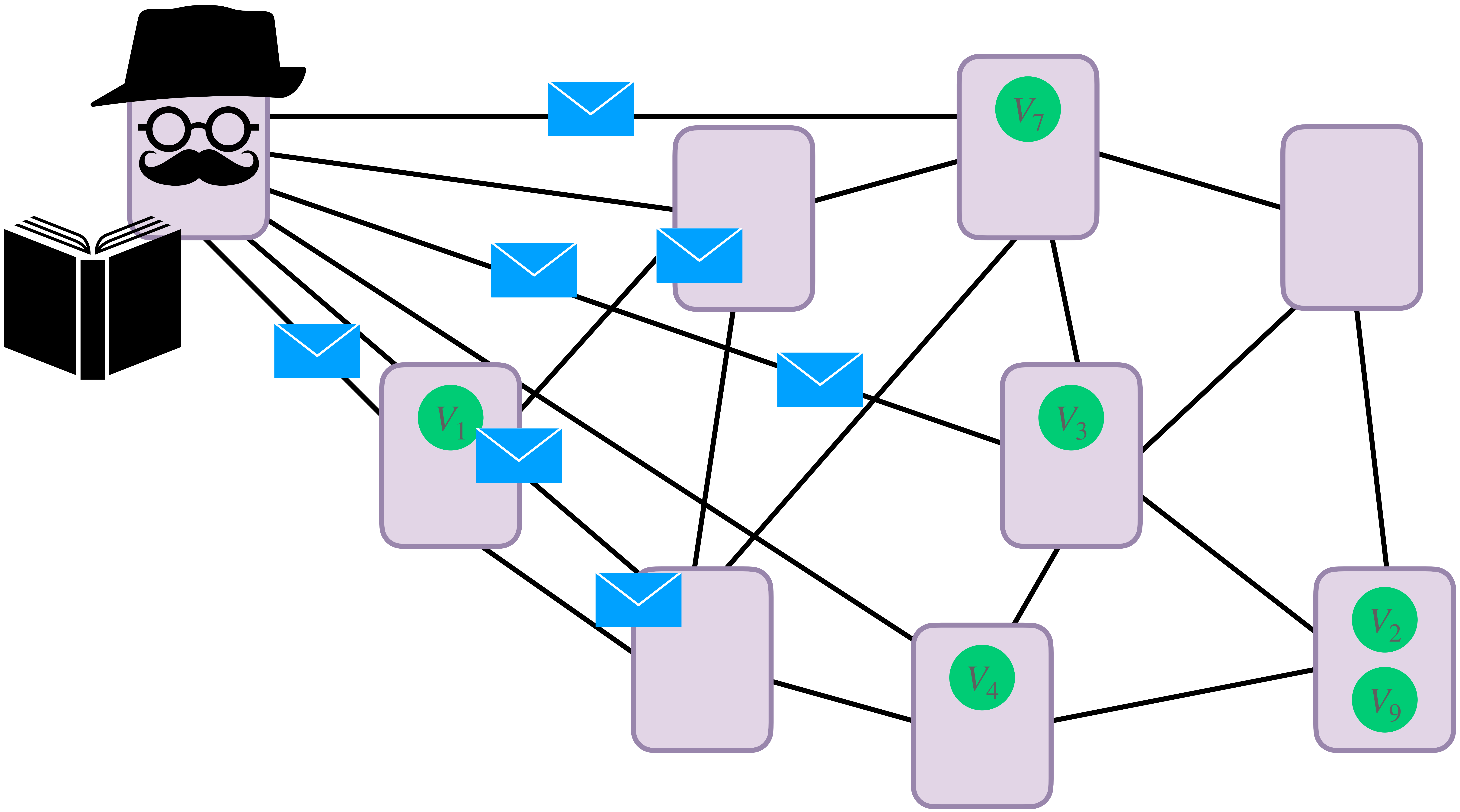

I am in
all subnets!
subnet 13
subnet 61
subnet 57
subnet 7
subnet 14
?
subnet 13
subnet 14

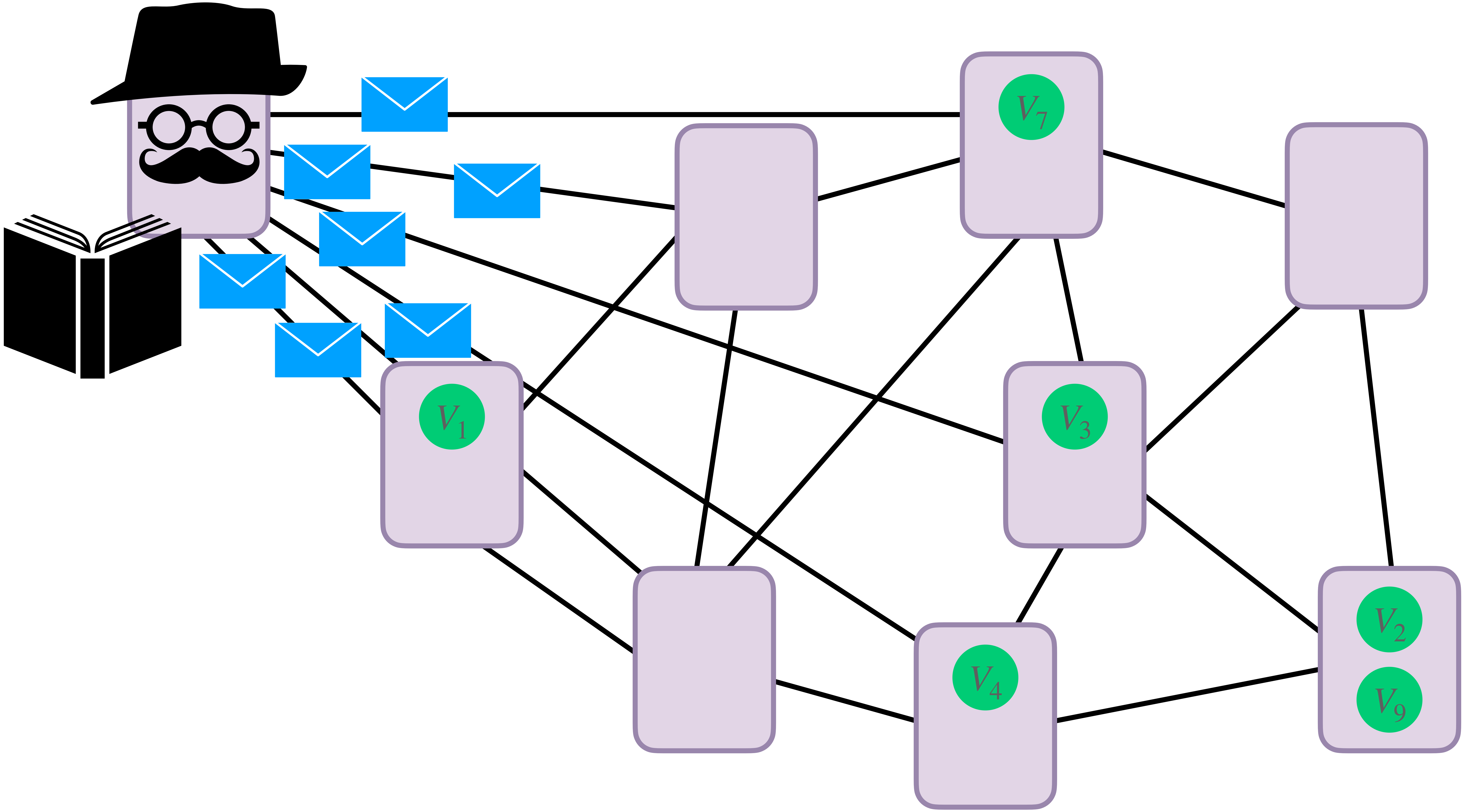

I am in
all subnets!
subnet 13
subnet 61
93
subnet 57
93
93
subnet 7
?
subnet 13
subnet 14
subnet 14


I am in
all subnets!
subnet 13
subnet 61
93
subnet 57
93
93
subnet 7
V_{93}
subnet 13
subnet 14
subnet 14

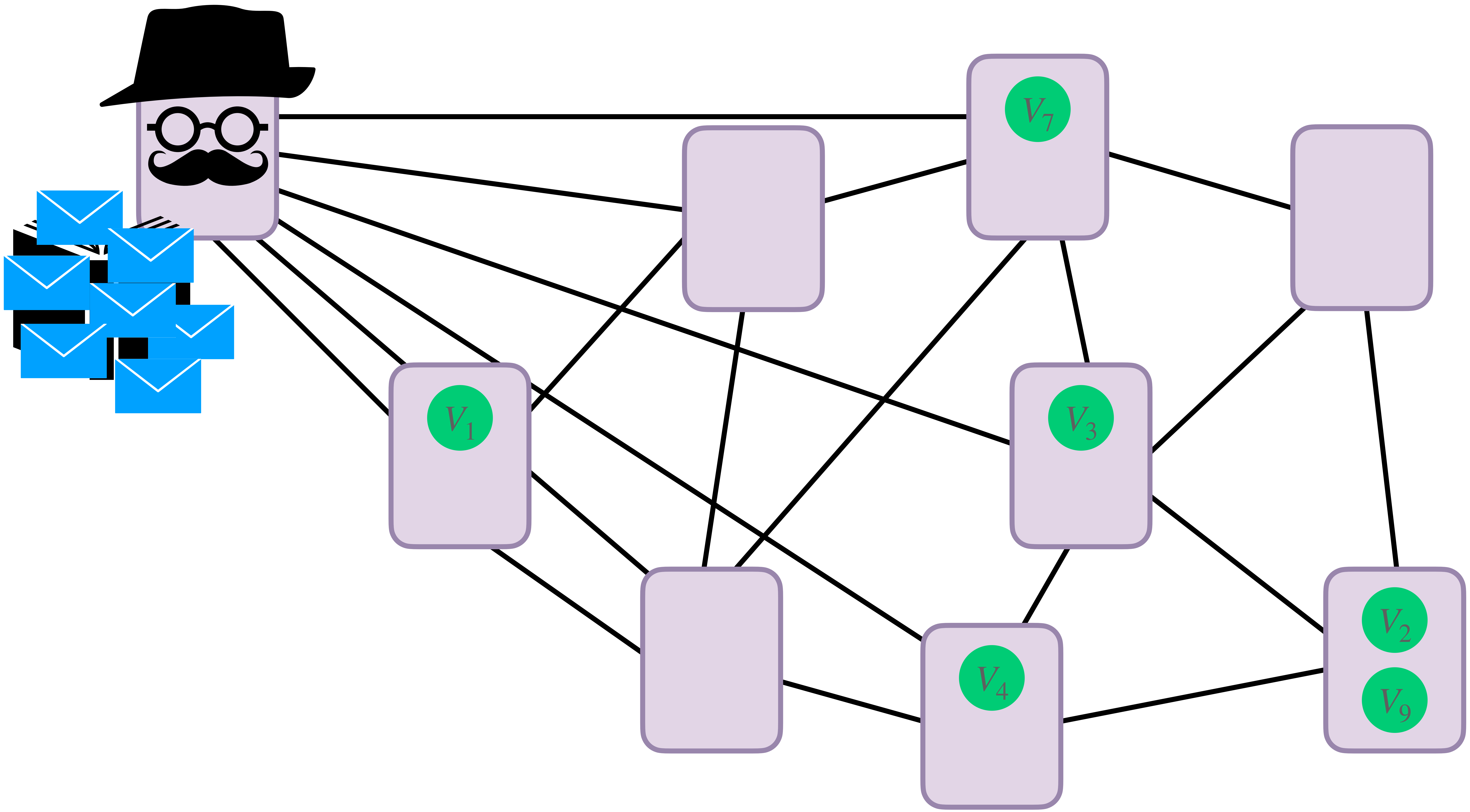

V_7
V_1
V_3
V_4
V_2
V_9

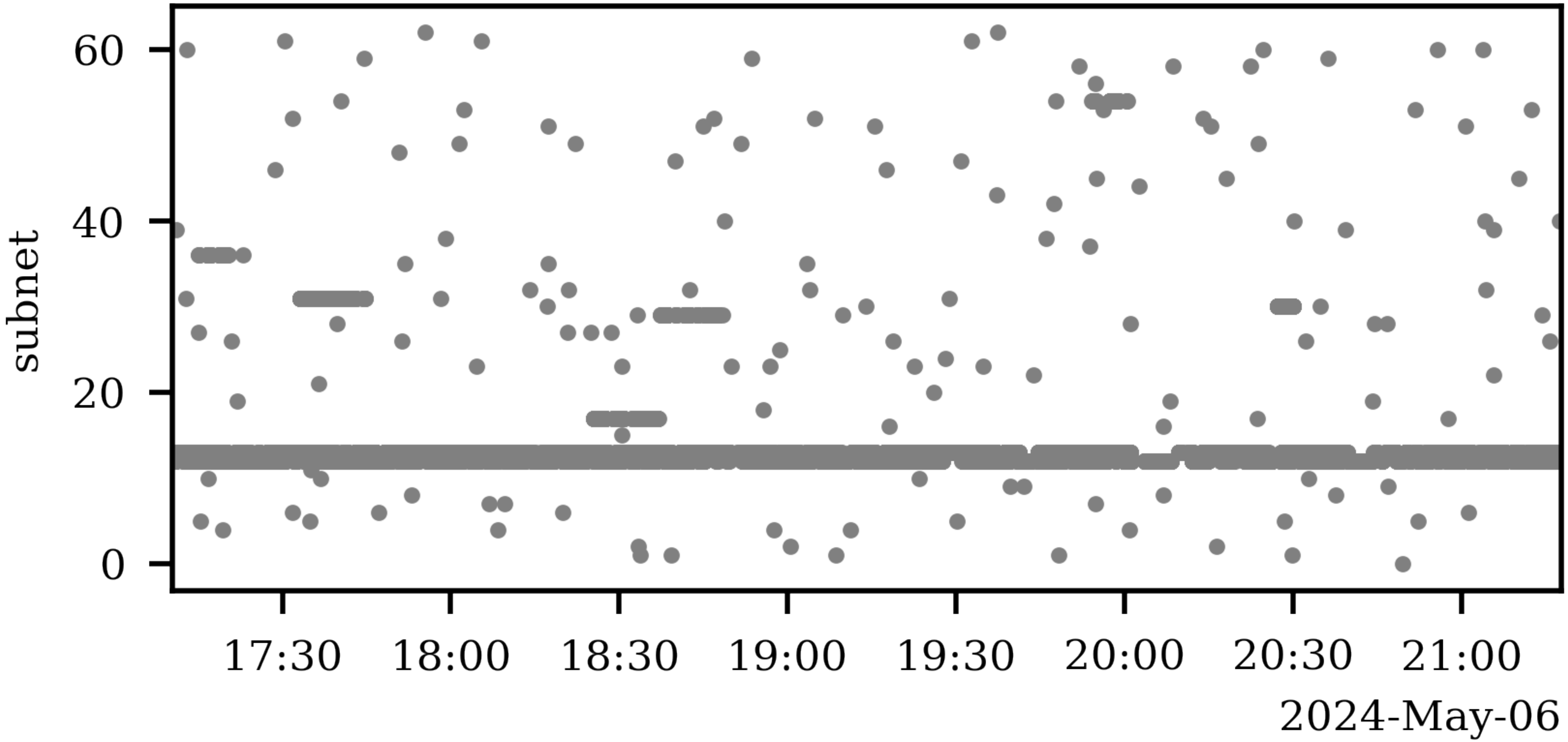

V_7
V_1
V_3
V_4
V_2
V_9

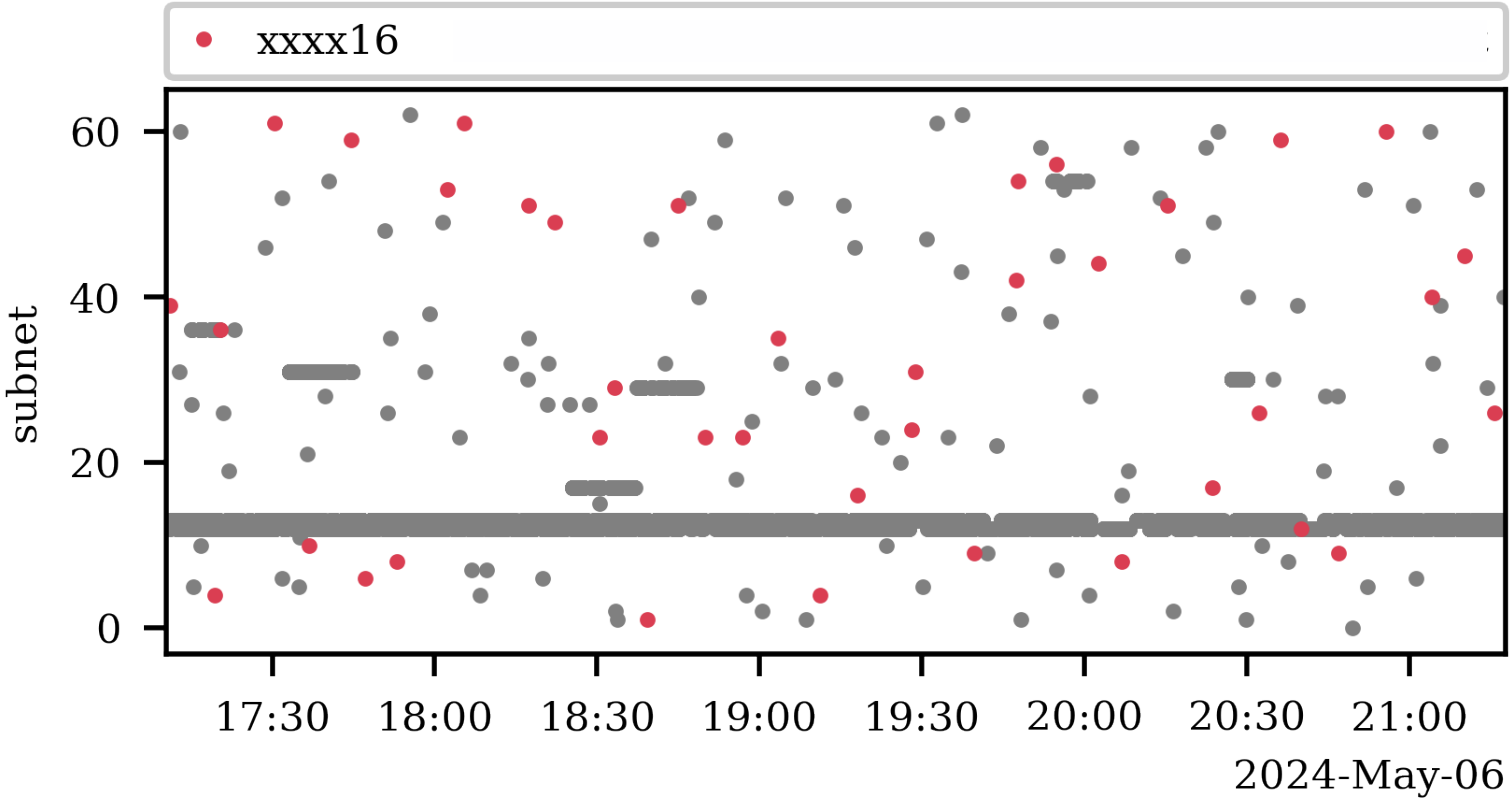

V_7
V_1
V_3
V_2
V_9
V_4

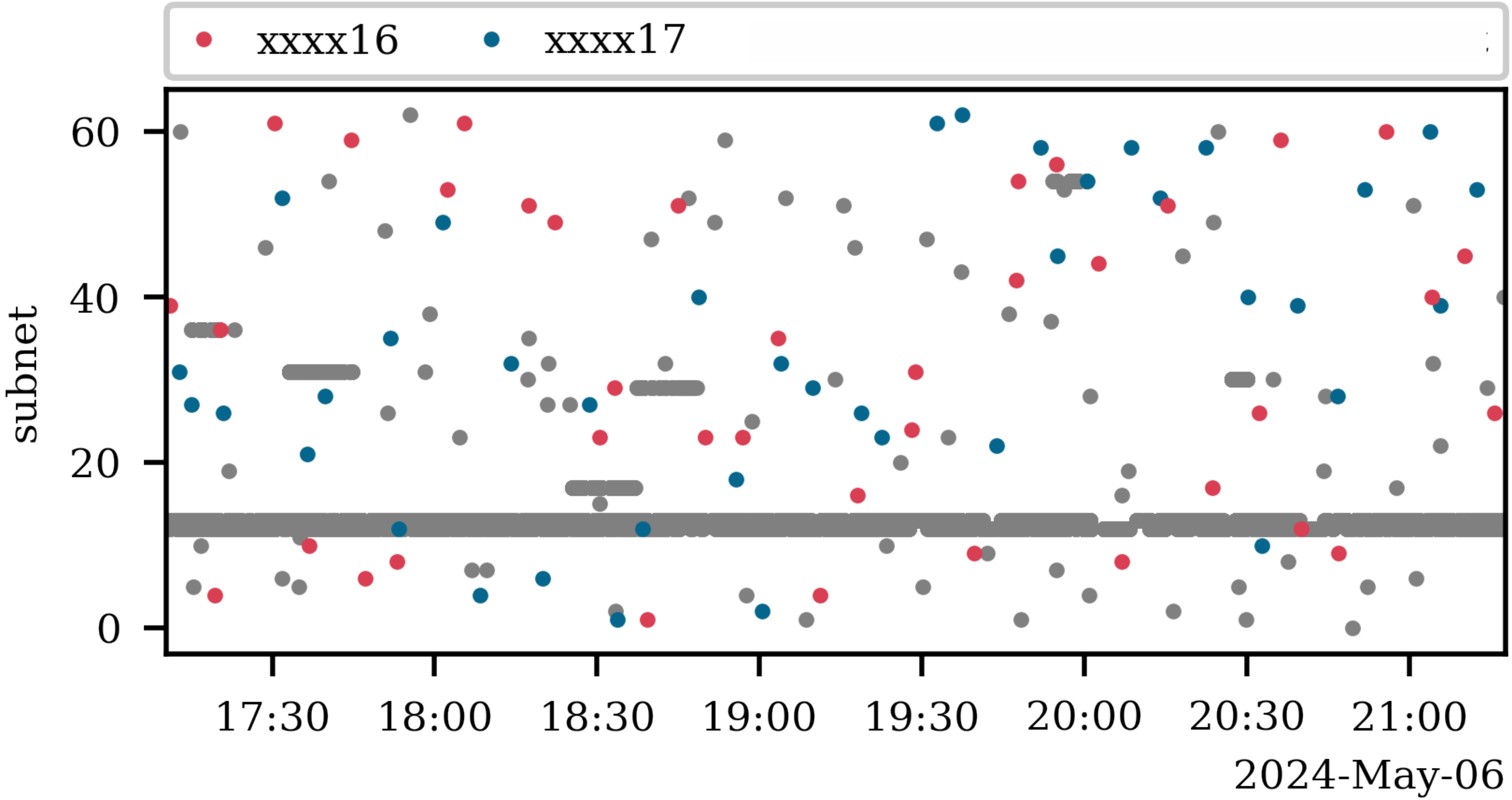


V_7
V_1
V_3
V_2
V_9
V_4

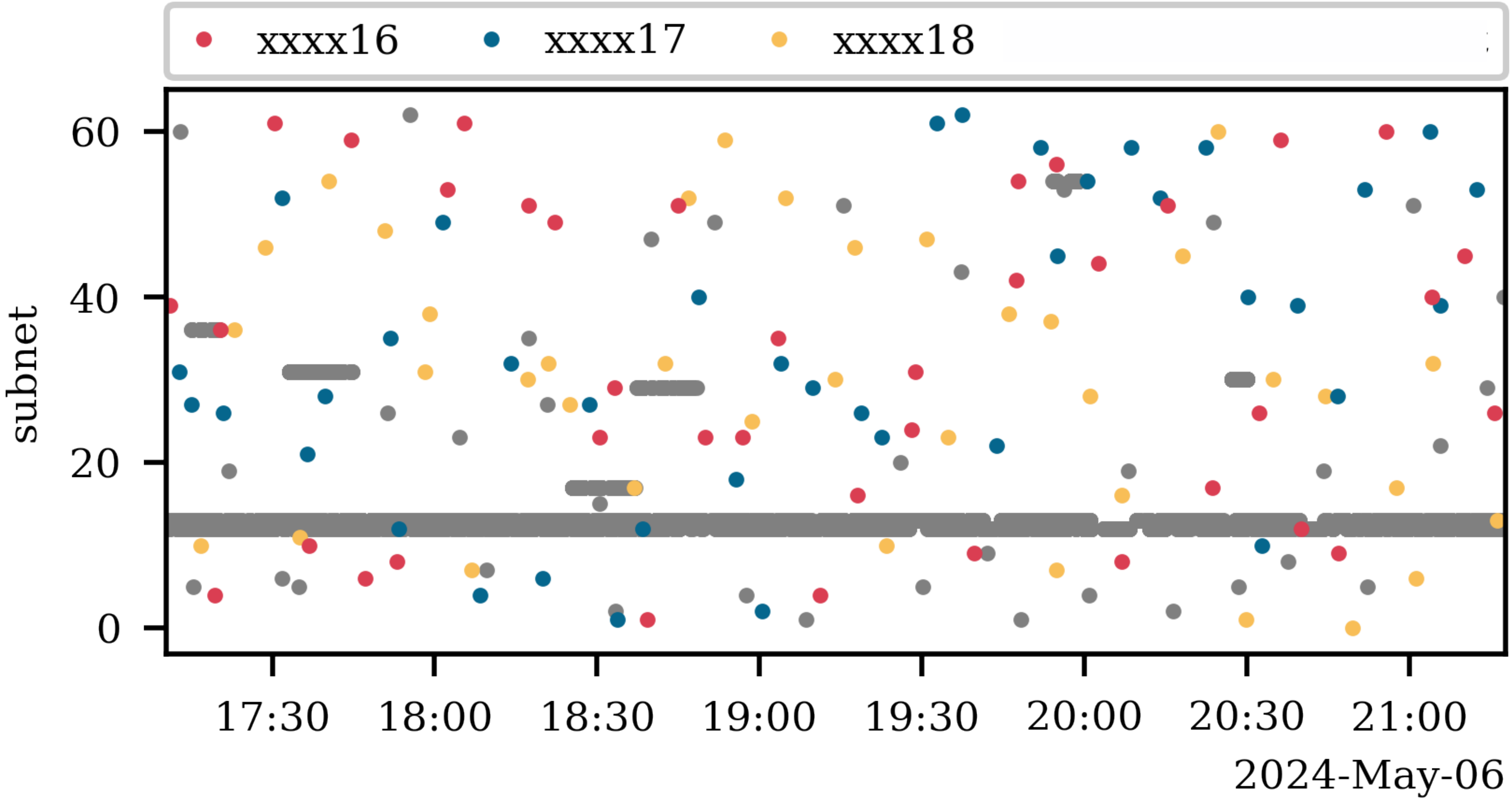

V_7
V_1
V_3
V_2
V_9
V_4

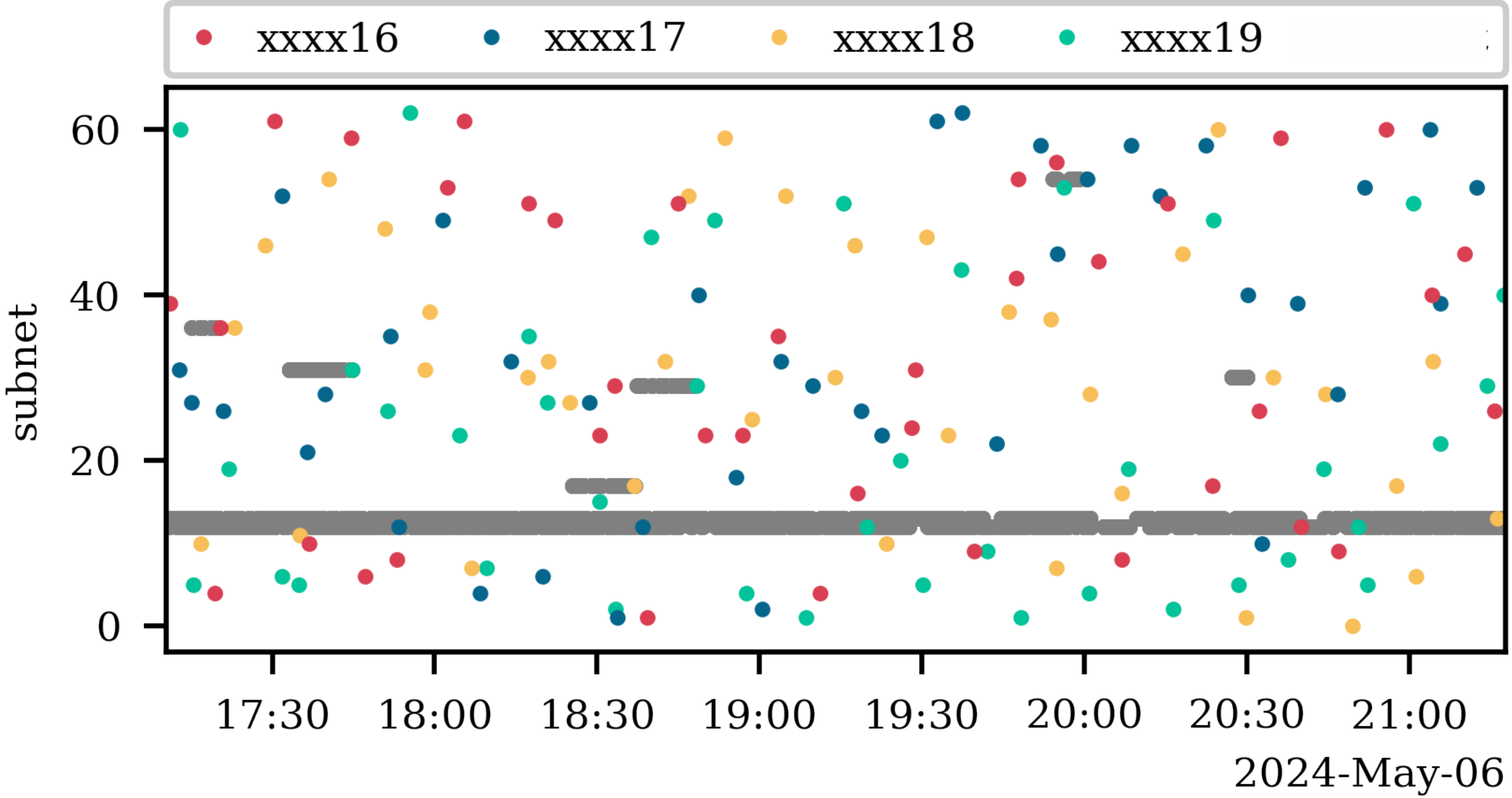

subnet
0
20
40
60
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
2024-May-06


xxxx16
subnet
60
40
20
0
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
2024-May-06

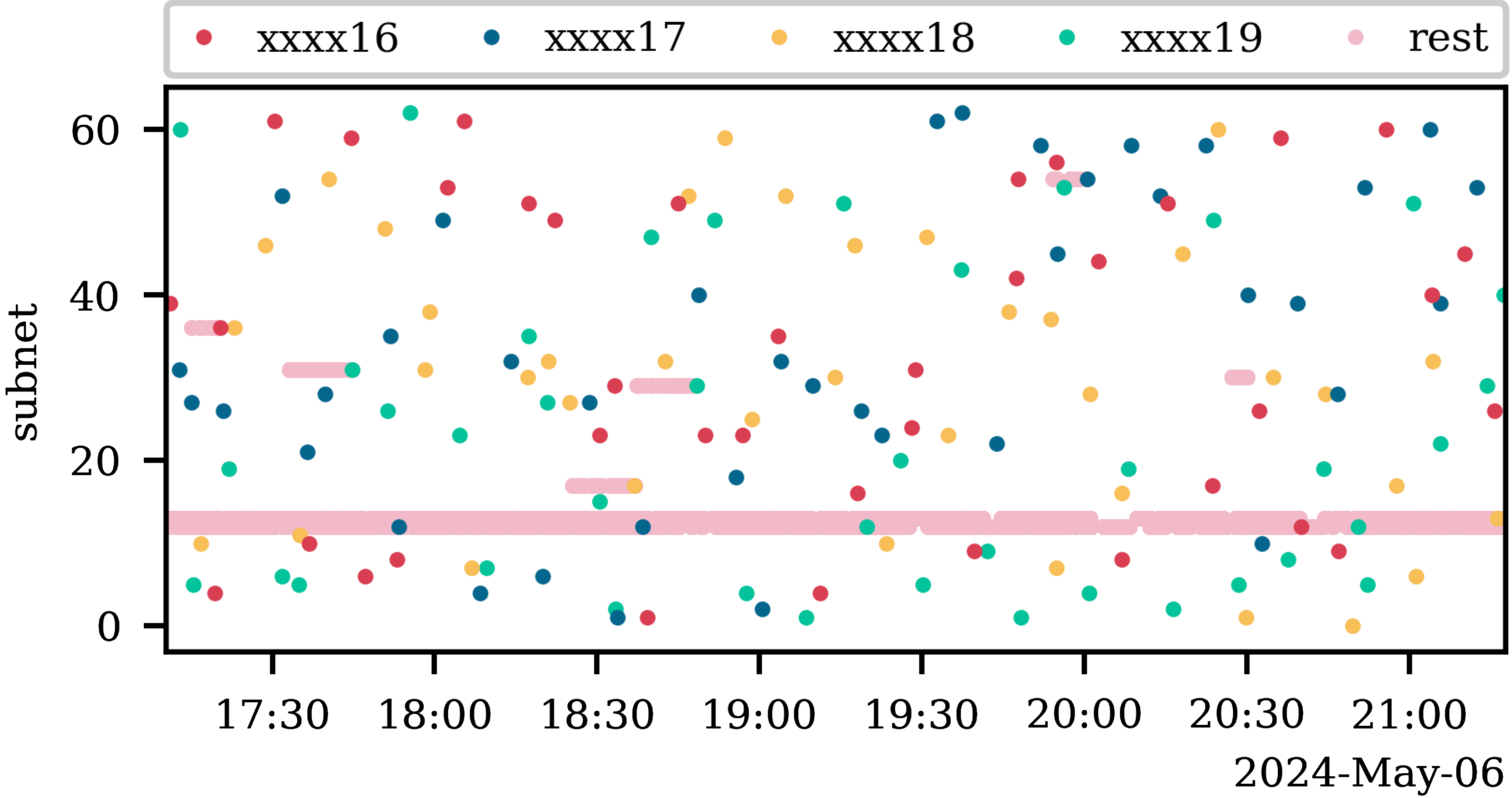


● xxxx16
● xxxx17
subnet
0
20
40
60
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
2024-May-06


● xxxx16
● xxxx17
● xxxx18
subnet
60
40
20
0
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
2024-May-06



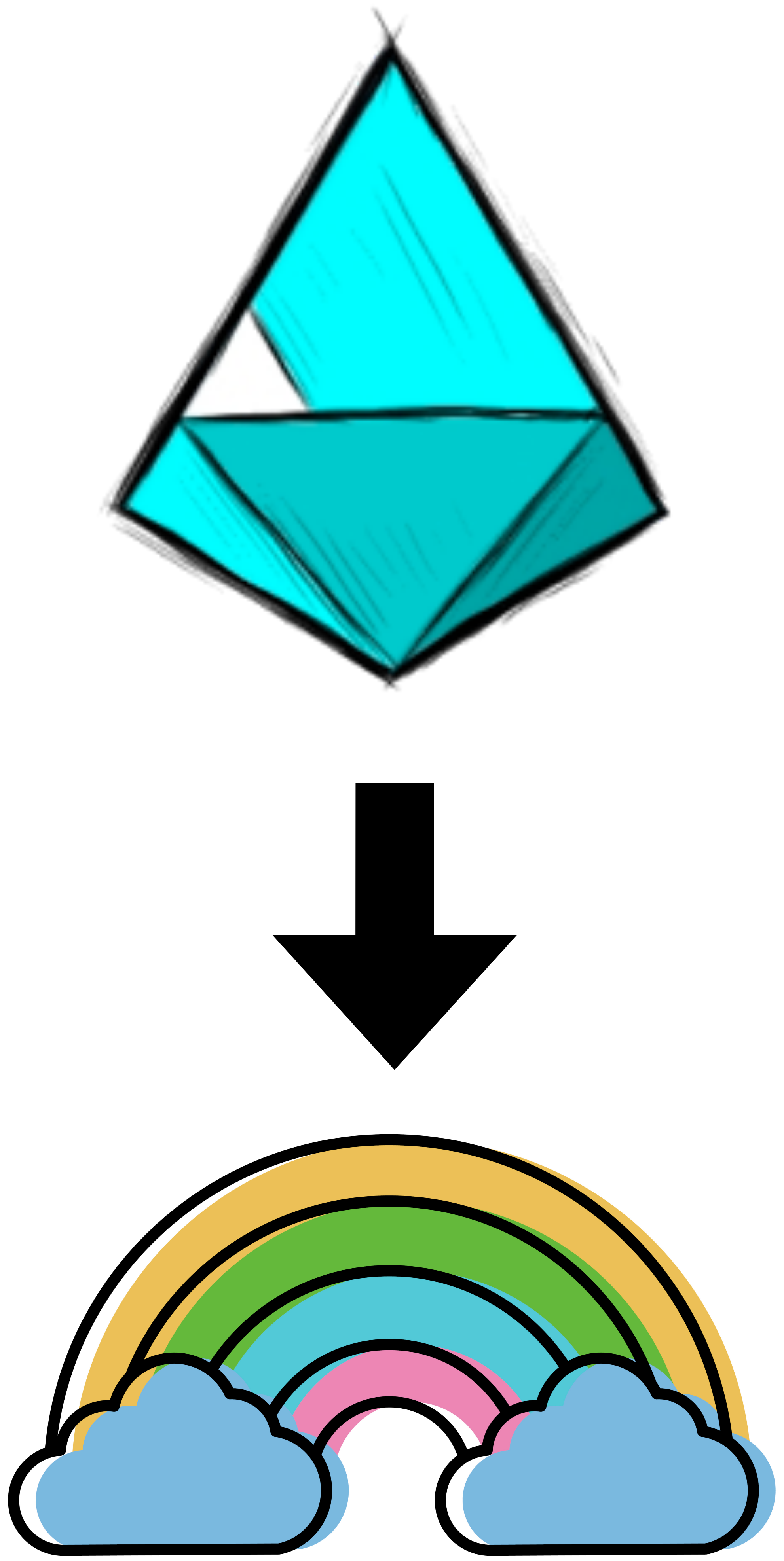
● xxxx16
● xxxx17
● xxxx18
● xxxx19
subnet
60
40
20
0
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
2024-May-06


● xxxx16
● xxxx17
● xxxx18
● xxxx19
● rest
subnet
0
20
40
60
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
2024-May-06

Measurement Methodology

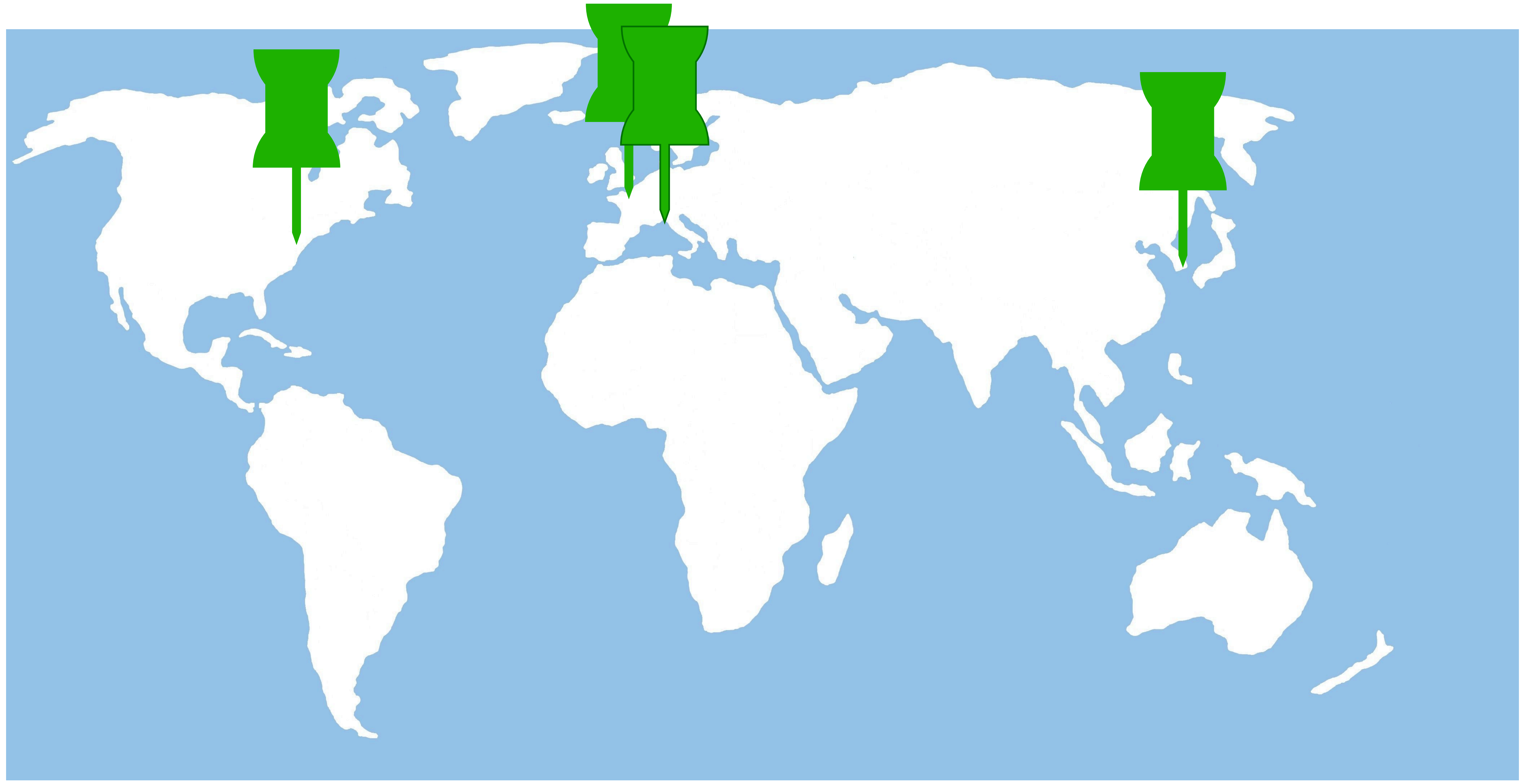
Methodology

- Create a logging client: RAINBOW



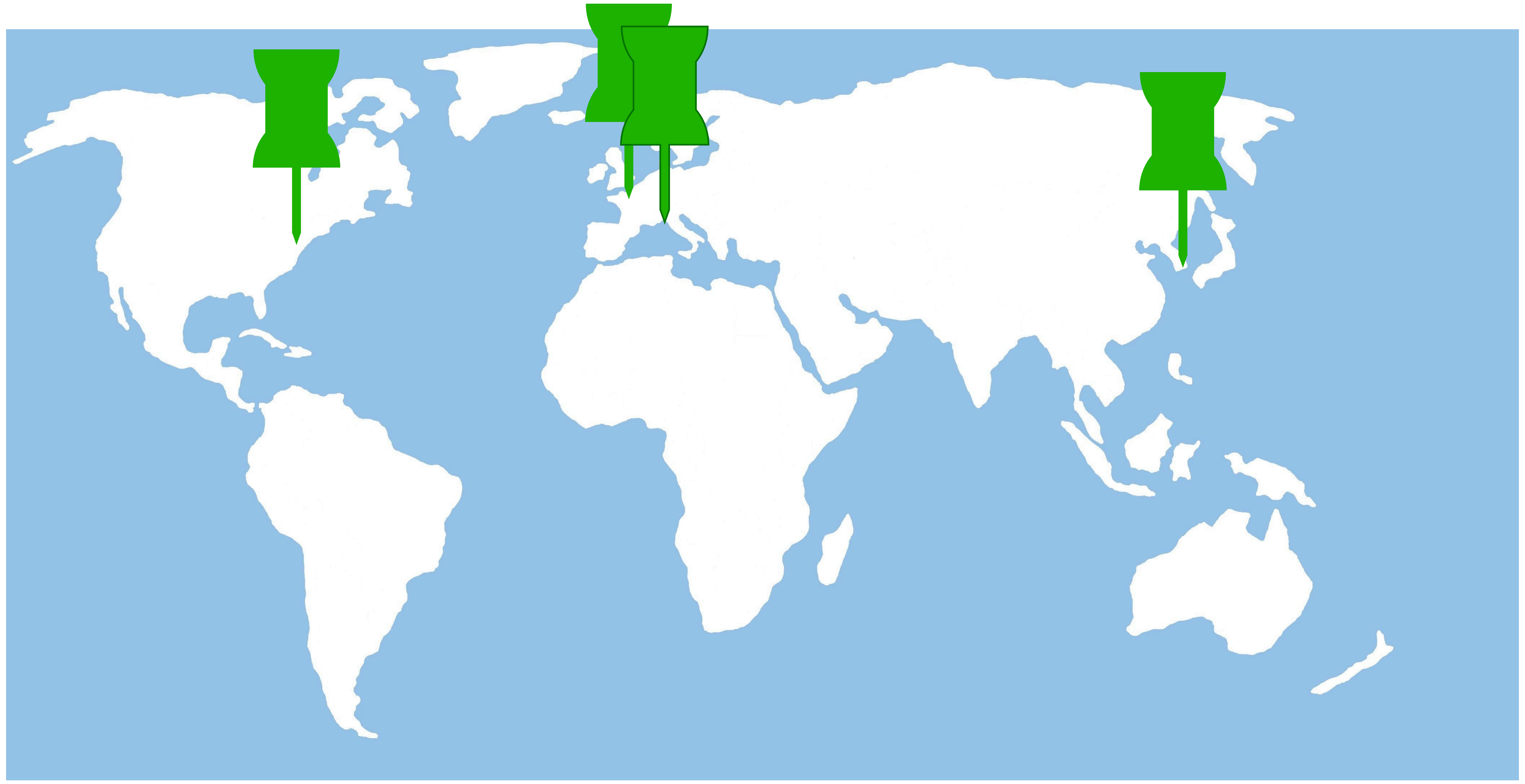
Methodology

- Create a logging client: RAINBOW
- Collect data on multiple locations for 3 days in May 2024



Methodology

- Create a logging client: RAINBOW
- Collect data on multiple locations for 3 days in May 2024
- Run a heuristic approach to deanonymization



Methodology

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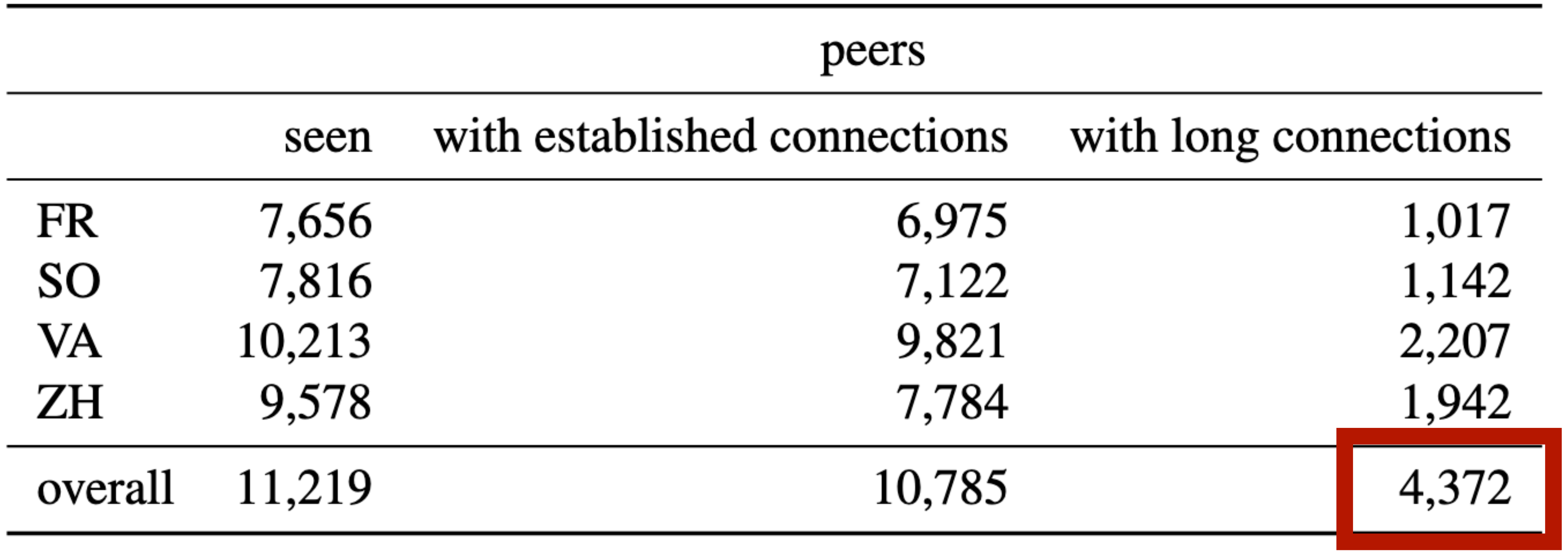
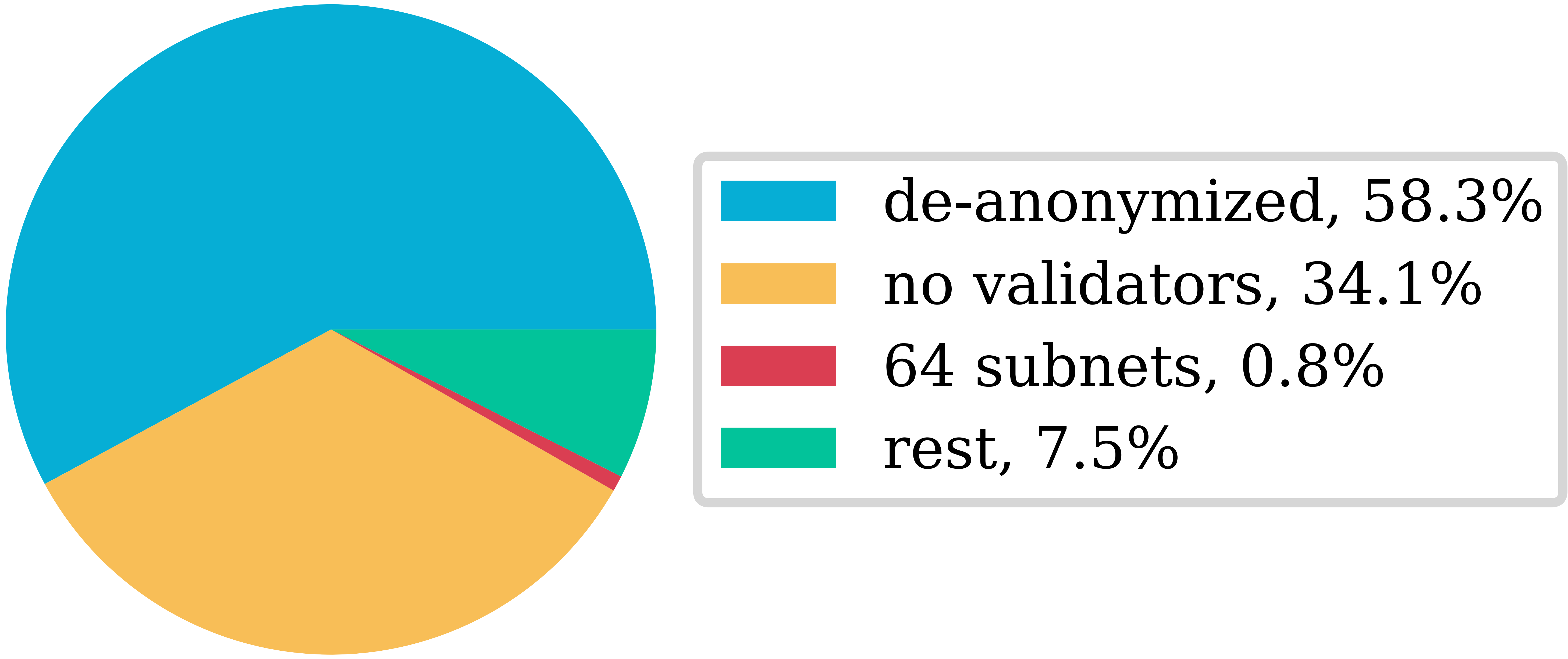


	peers		
	seen	with established connections	with long connections
FR	7,656	6,975	1,017
SO	7,816	7,122	1,142
VA	10,213	9,821	2,207
ZH	9,578	7,784	1,942
overall	11,219	10,785	4,372

Results

Results

Zurich, bare-bones, 1942 long connections



154’591

validators were deanonymized.

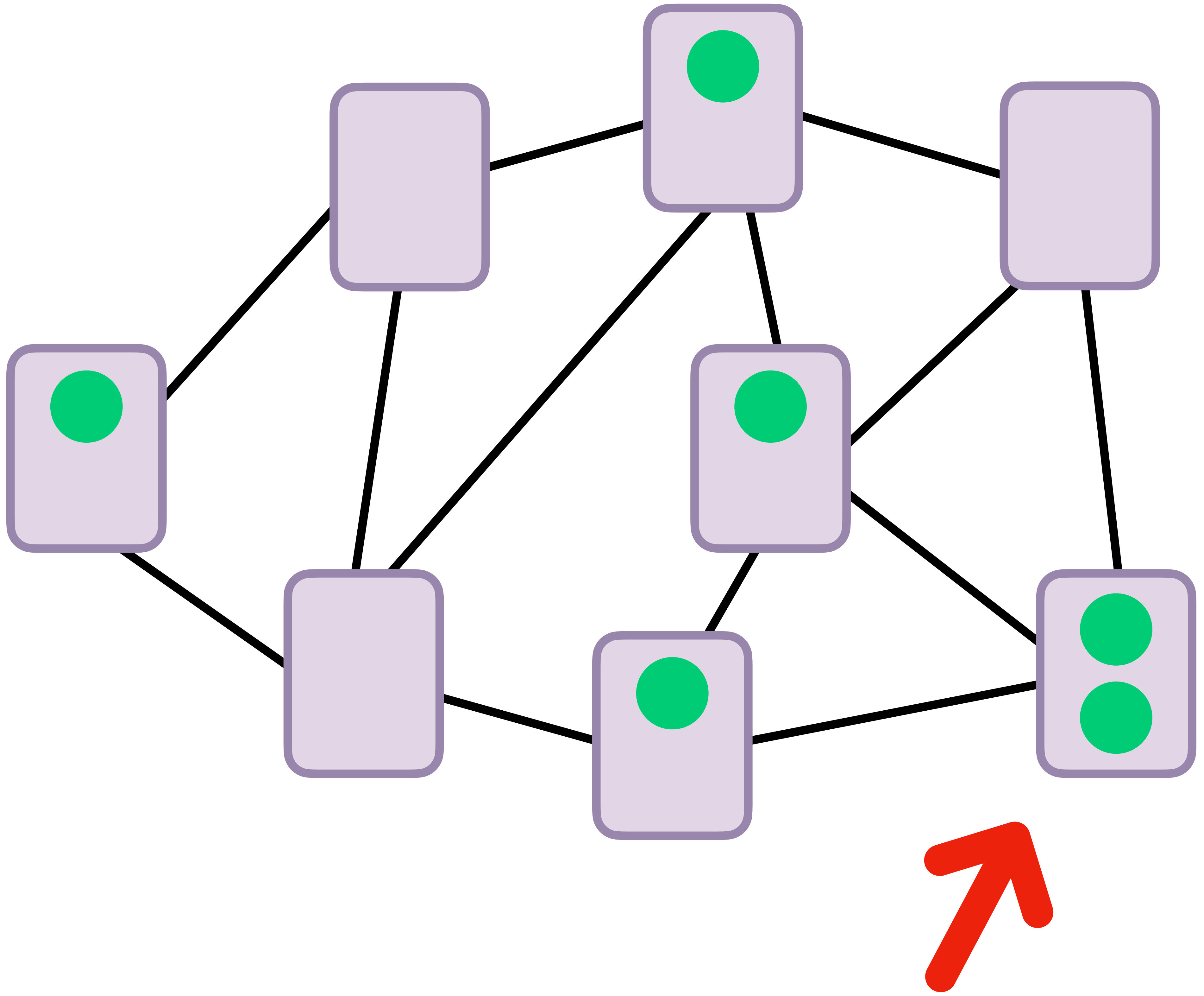
16%

of all validators were deanonymized.

Verification

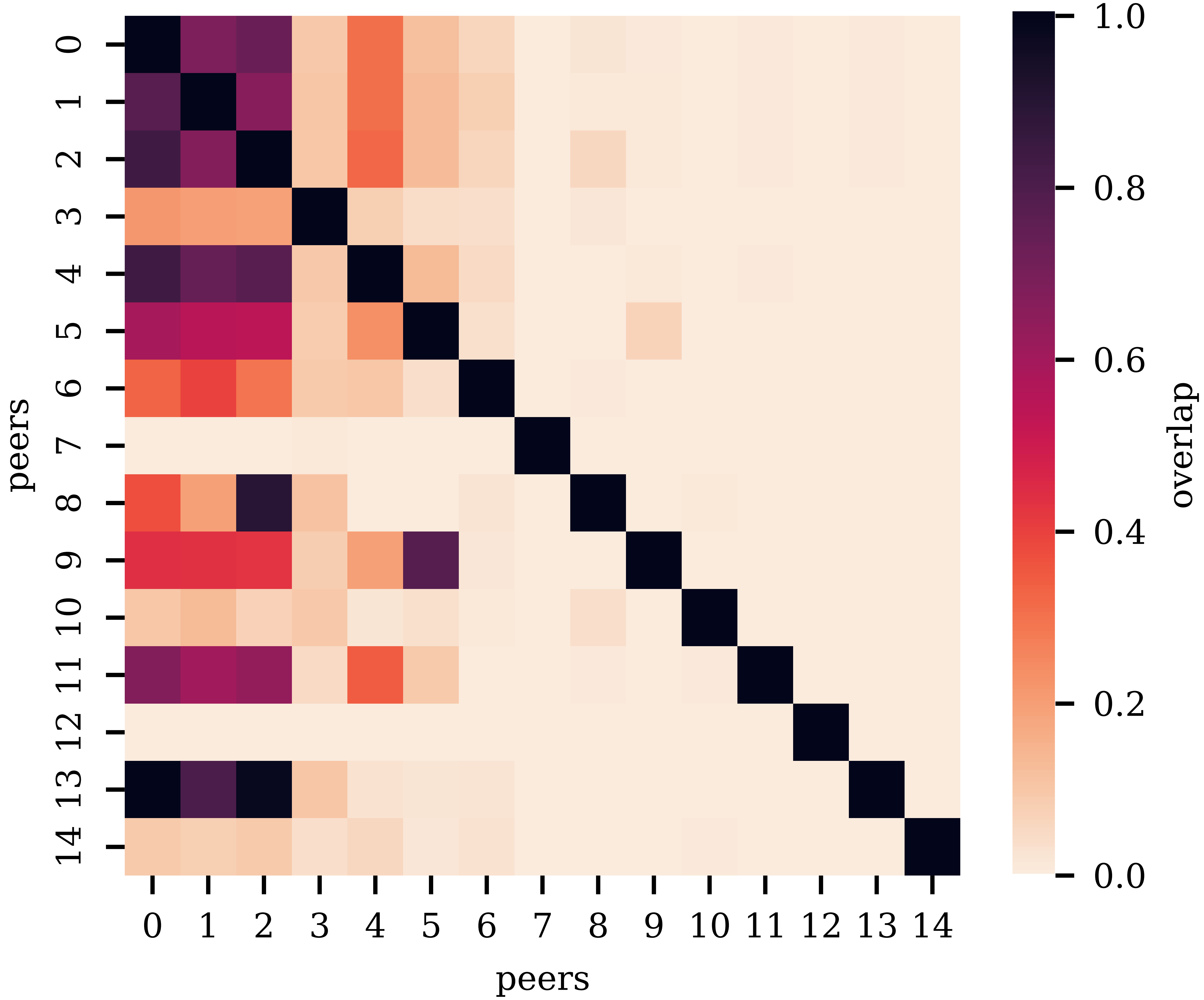
Verification

- **Consistency** of validators
  - Same staking pool
  - Same deposit address
  - Same fee recipient address
  - Consecutive IDs



Verification

- **Consistency** of validators
  - Same staking pool
  - Same deposit address
  - Same fee recipient address
  - Consecutive IDs
- **Uniqueness** of Validator-IP Mapping



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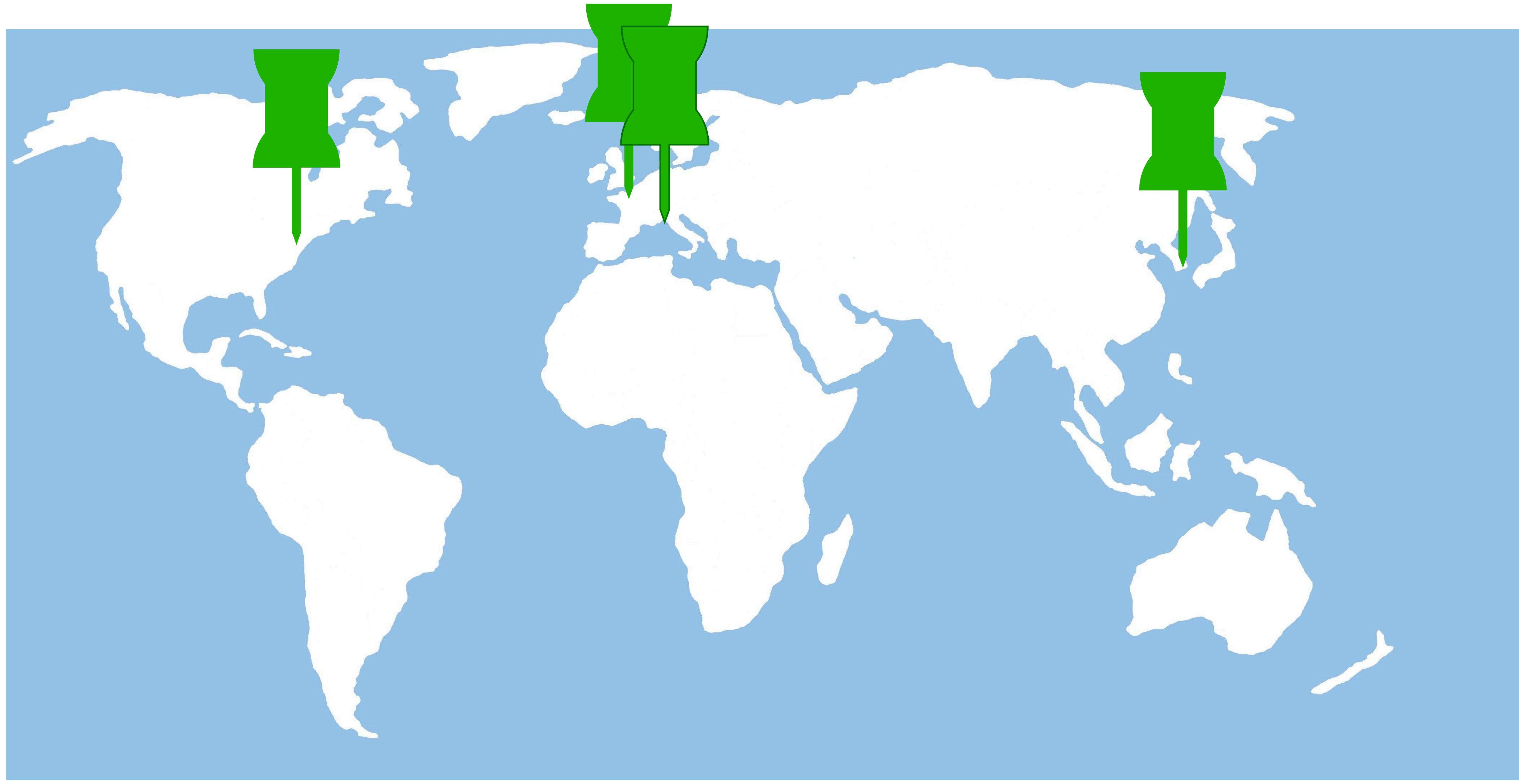
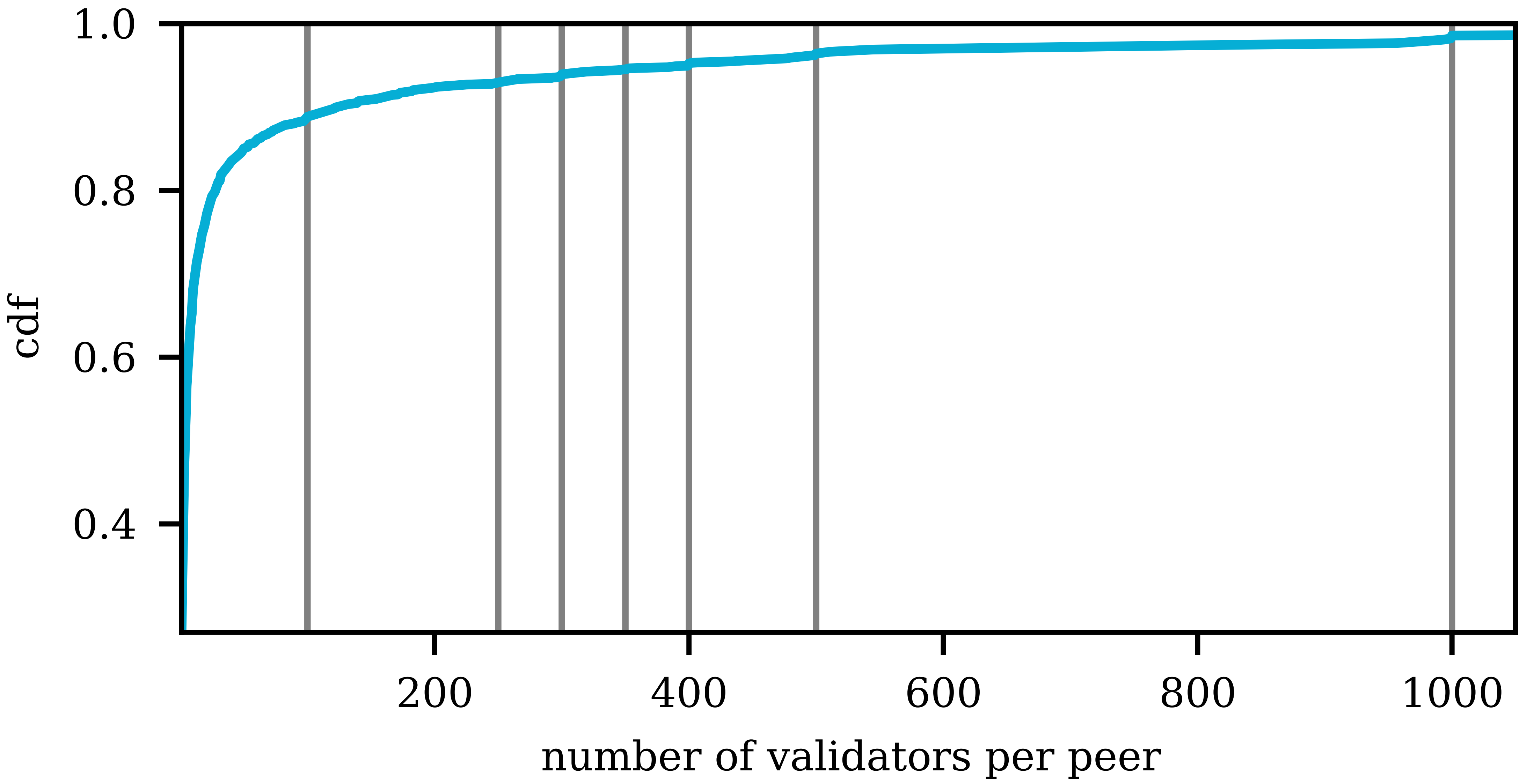
  - Consecutive IDs
- **Uniqueness** of Validator-IP Mapping
- **Similarity** of De-anonymizations



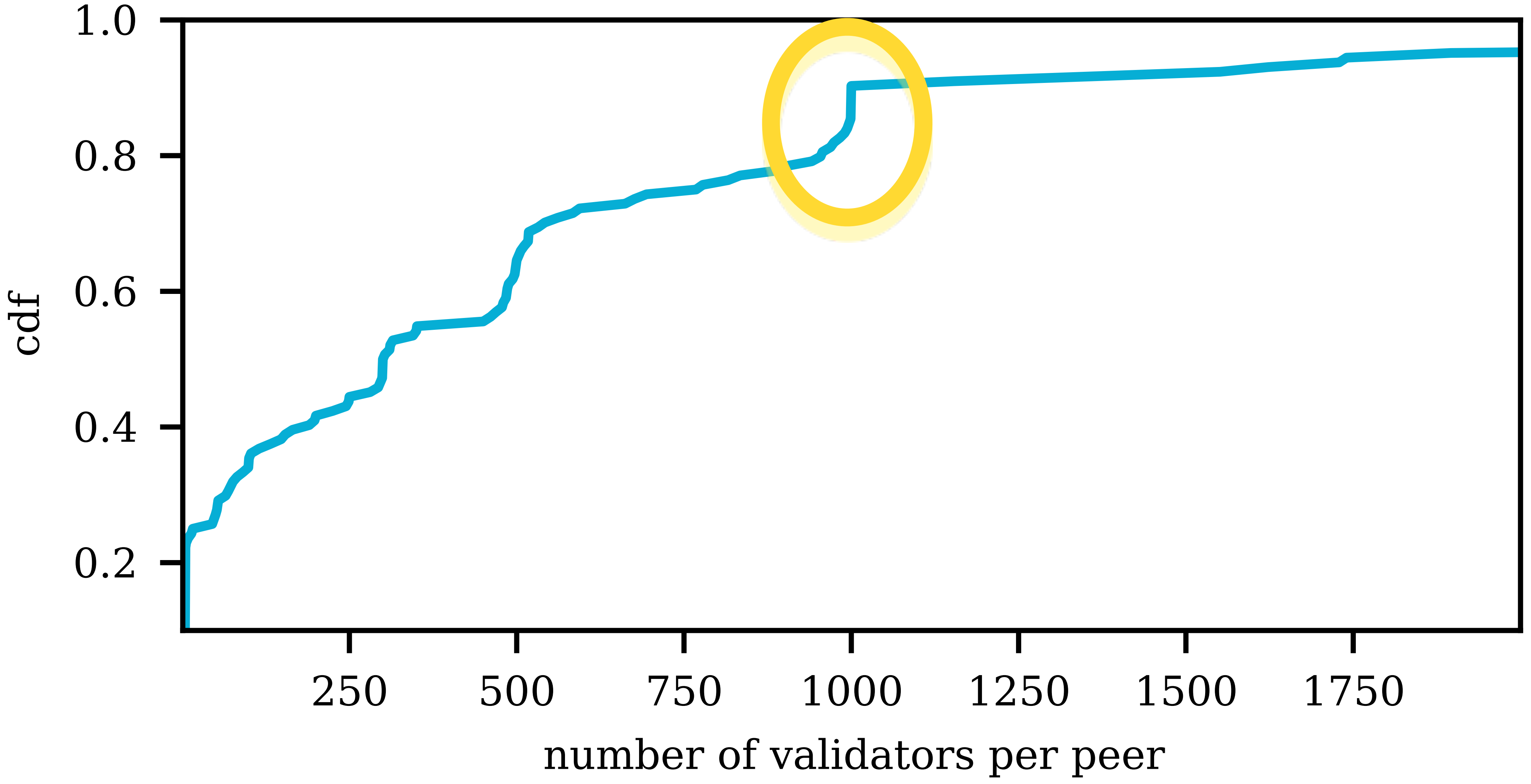
Take-aways

Validators per Peer

Overall

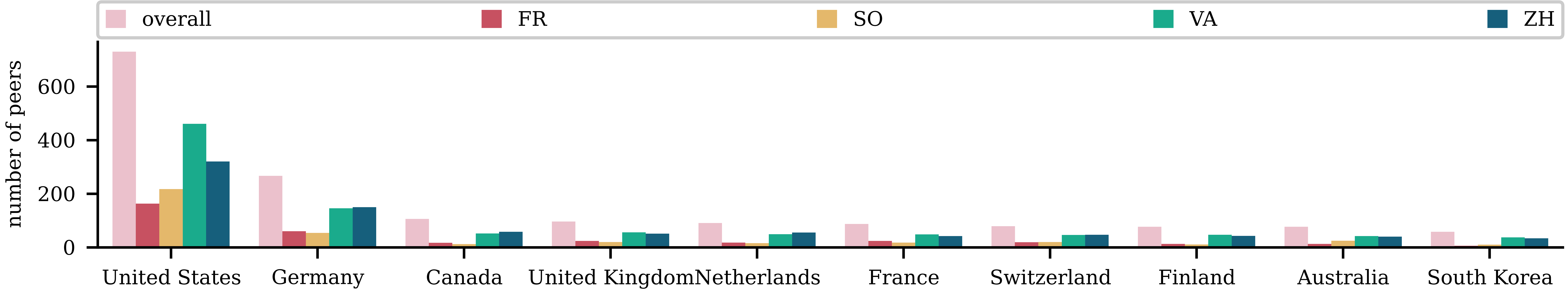


Five Largest Staking Pools

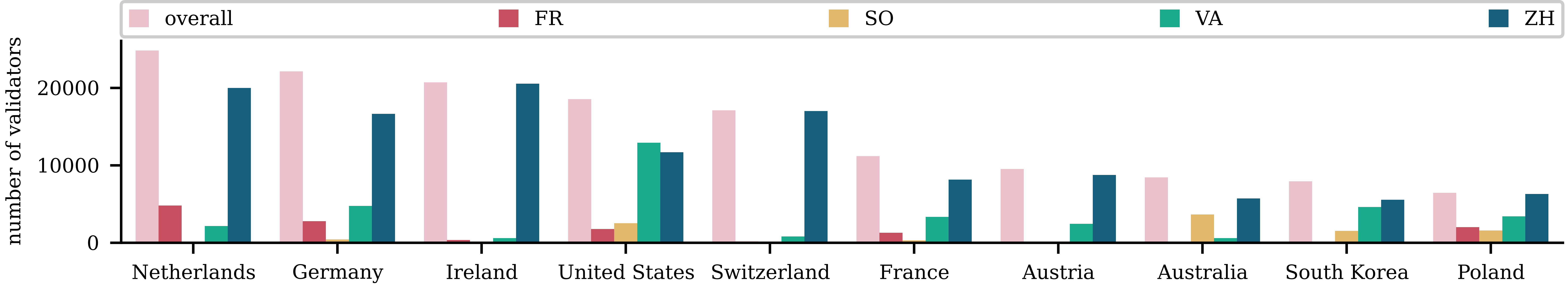


Location

Peers

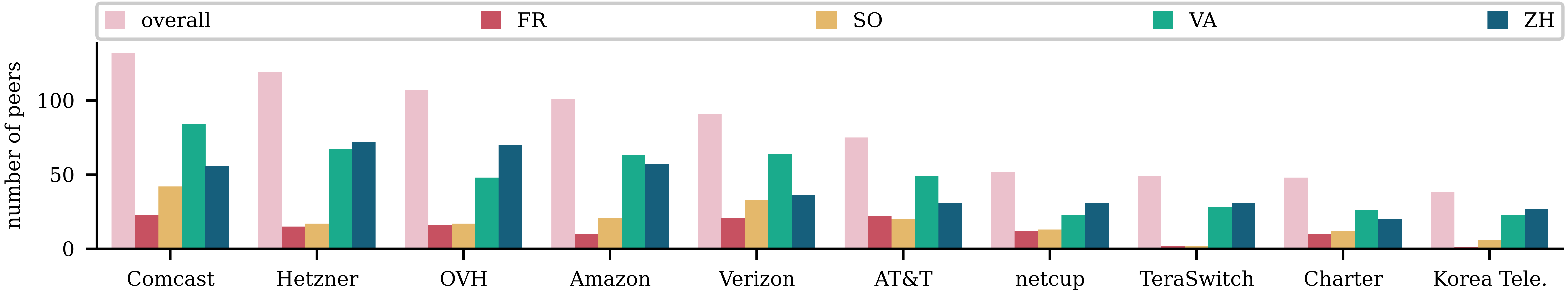


Validators

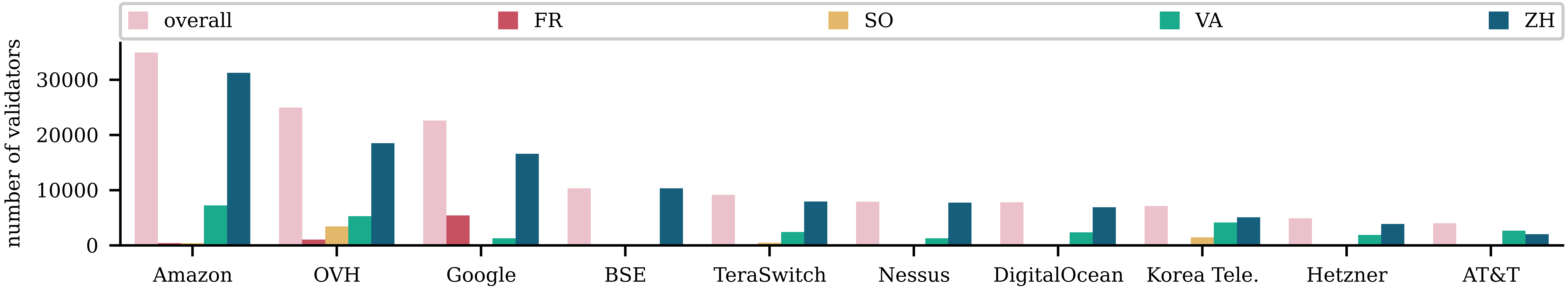


Organizations

Peers



Validators



Summary

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    - low-cost, high-accuracy

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  - increase anonymity set with friends
  - anonymous gossiping

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  - low-cost, high-accuracy
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  - increase anonymity set with friends
  - anonymous gossiping
- Reported attack to Ethereum Foundation + a grant for followup work on the gossip protocol

Thanks!

paper