

StAN

Exploiting Shared Interests without Disclosing Them in Gossip-based Publish/Subscribe

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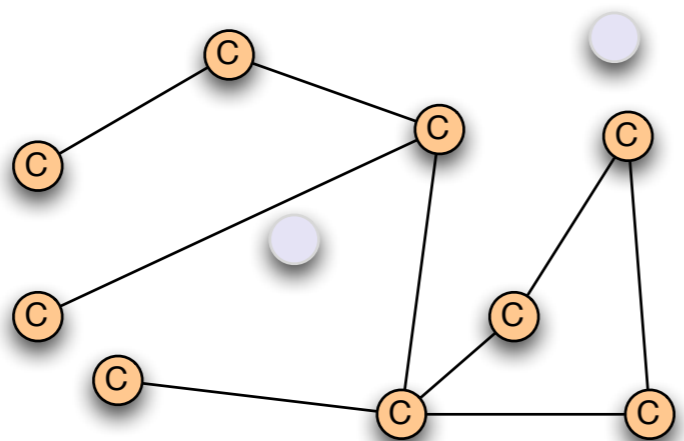
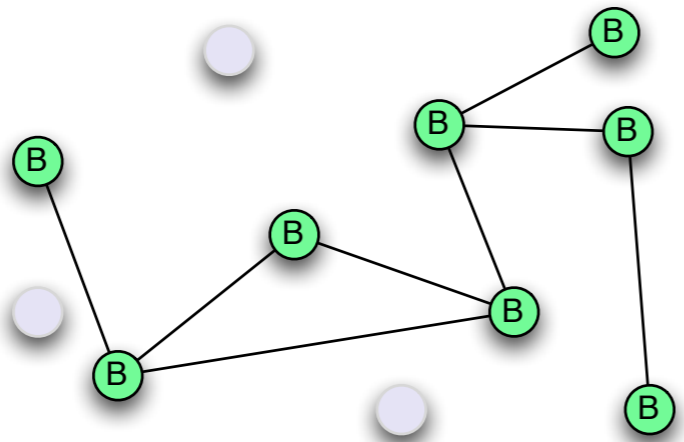
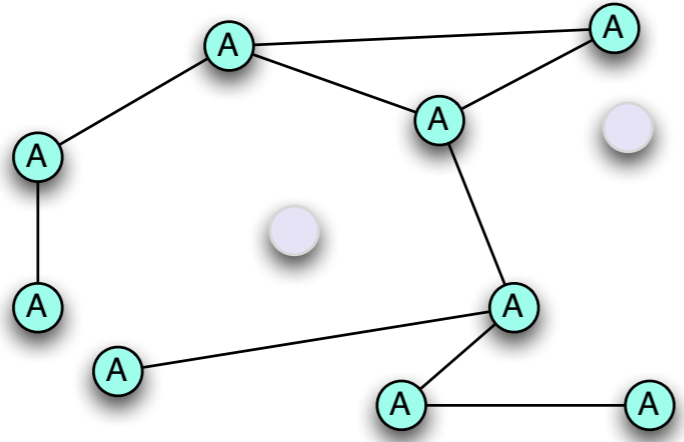


Problem statement

- Efficient, decentralized topic-based routing.
- Bringing nodes with shared interests closer makes gossip more efficient.
- Unfortunately, this usually requires fully disclosing interests to nearby nodes.
- Reliability is impacted due to clustering.



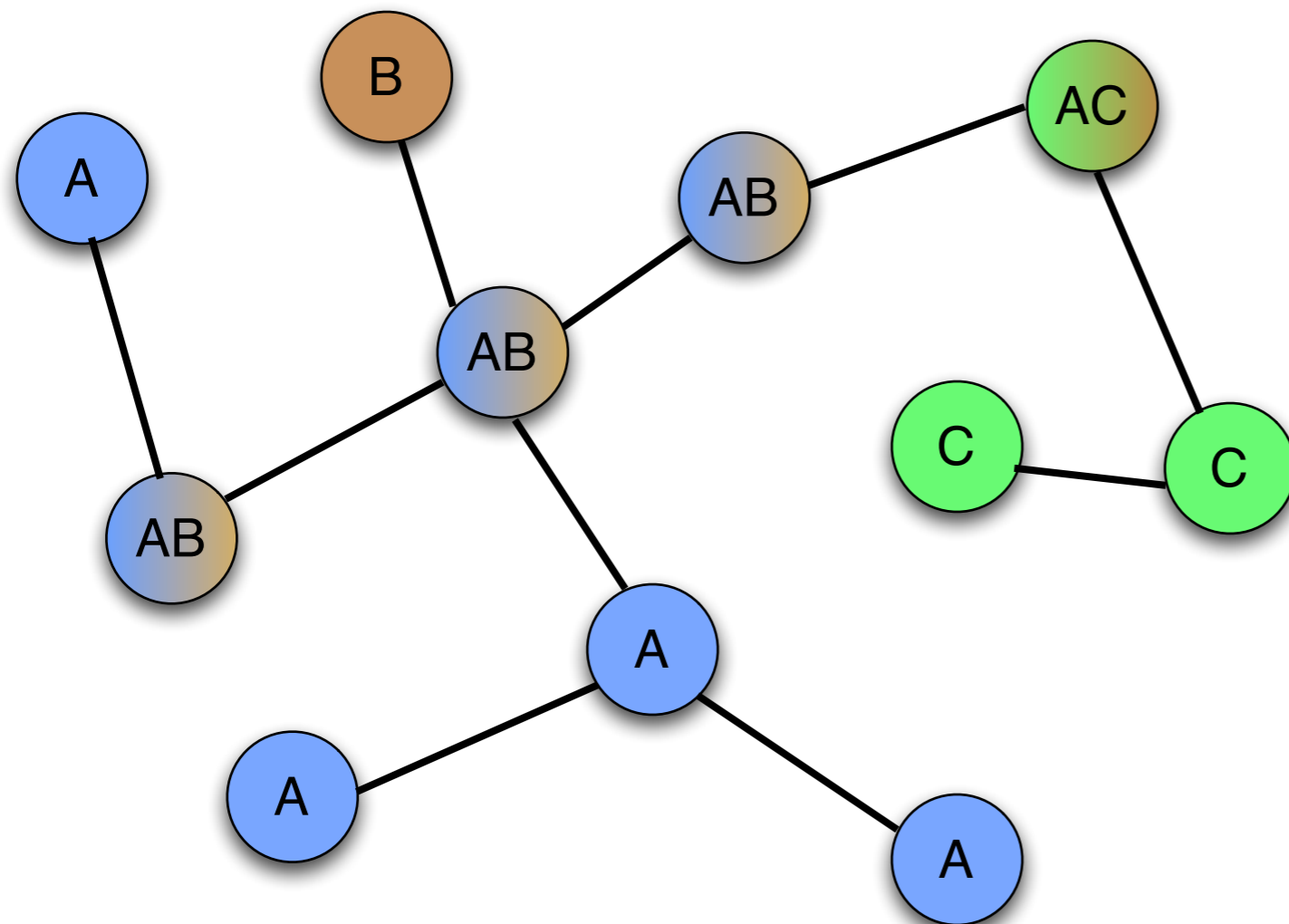
An overlay per topic



- nodes join overlays independently
- increases maintenance overhead
- redundant retransmissions



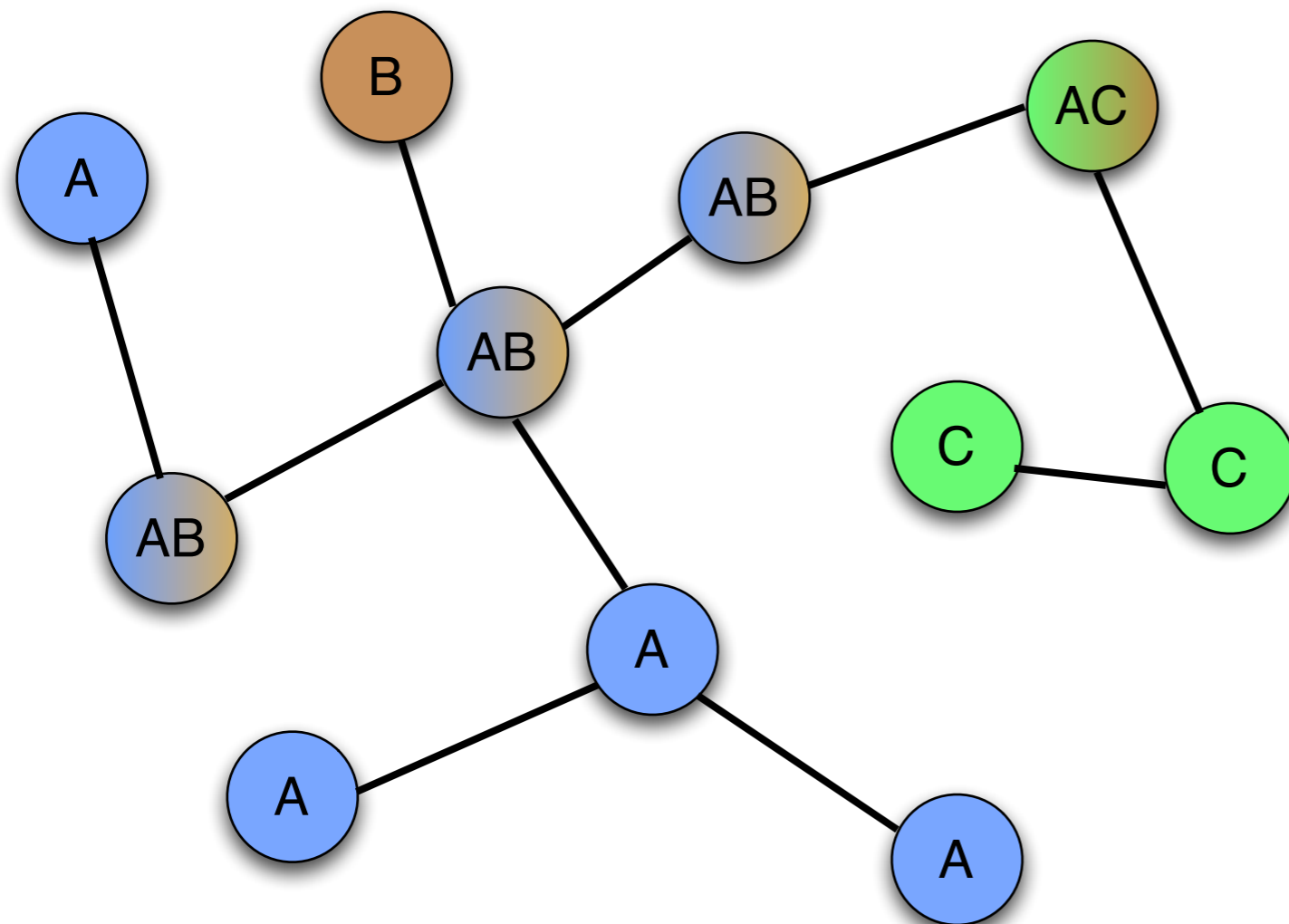
A single overlay



- shared interests recognized and disclosed
- network overhead
- no privacy
- redundant retransmissions avoided



A single overlay



- with global knowledge, dissemination can be done efficiently
- building a minimal graph is NP-complete
- high clustering coefficient
- prone to partitioning



StAN

- Assumptions
- How to optimize the overlays
- Node discovery



StAN

Multiple stacked aligned overlays, that

- are managed independently
- converge to share a large number of physical links
- retain desirable properties for gossiping

scalability

resilience



Assumptions

- Topic popularity follows a power-law distribution.
- The number of subscriptions per node also follows a power-law distribution.
- Subscriptions are strongly correlated.
- There is a non-negligible overlap in subscription sets.



The initial overlays

- A separate random overlay for each topic such that:

- degree grows logarithmically with system size

scalability

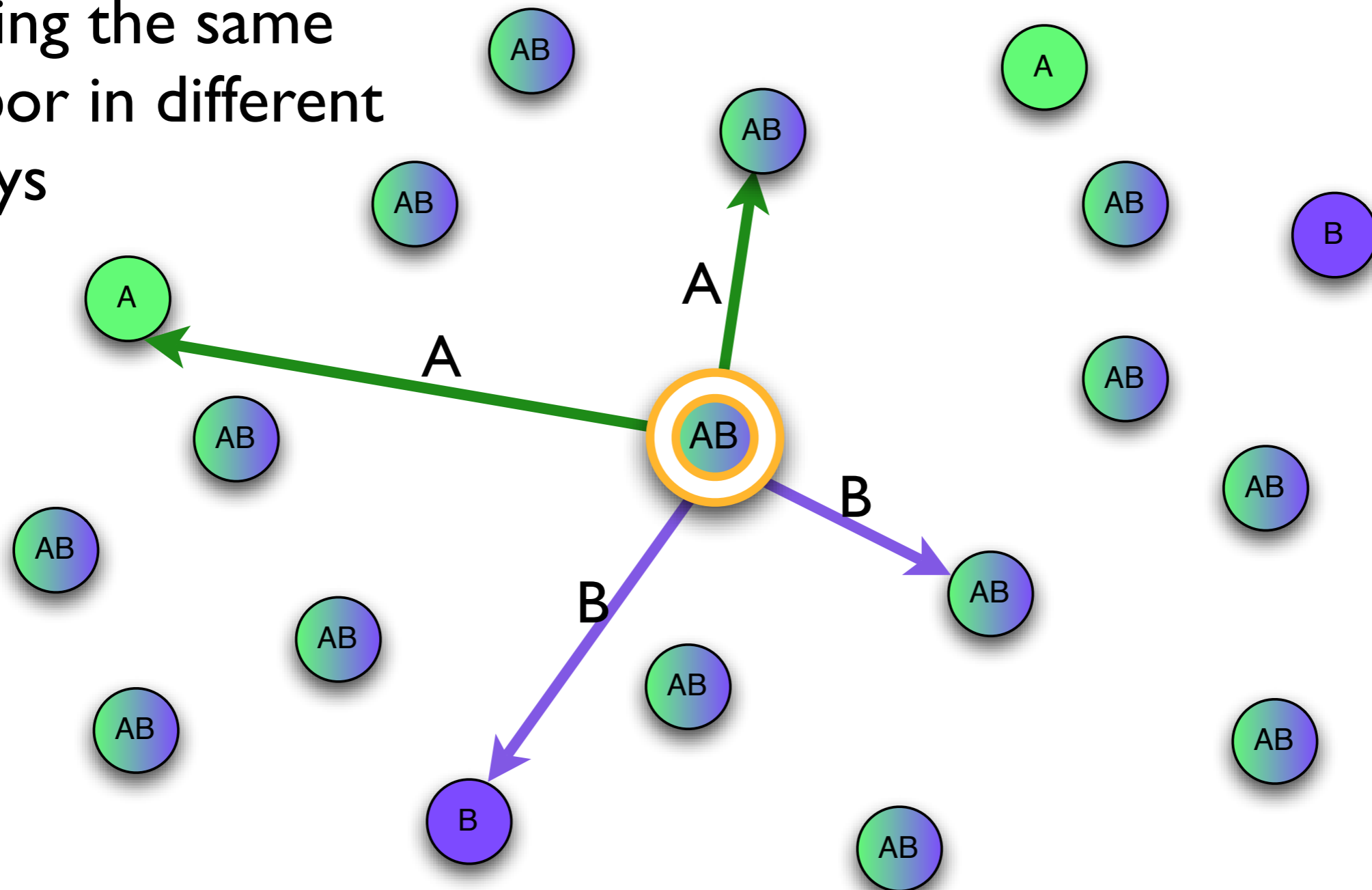
- clustering is low

resilience



The initial overlays

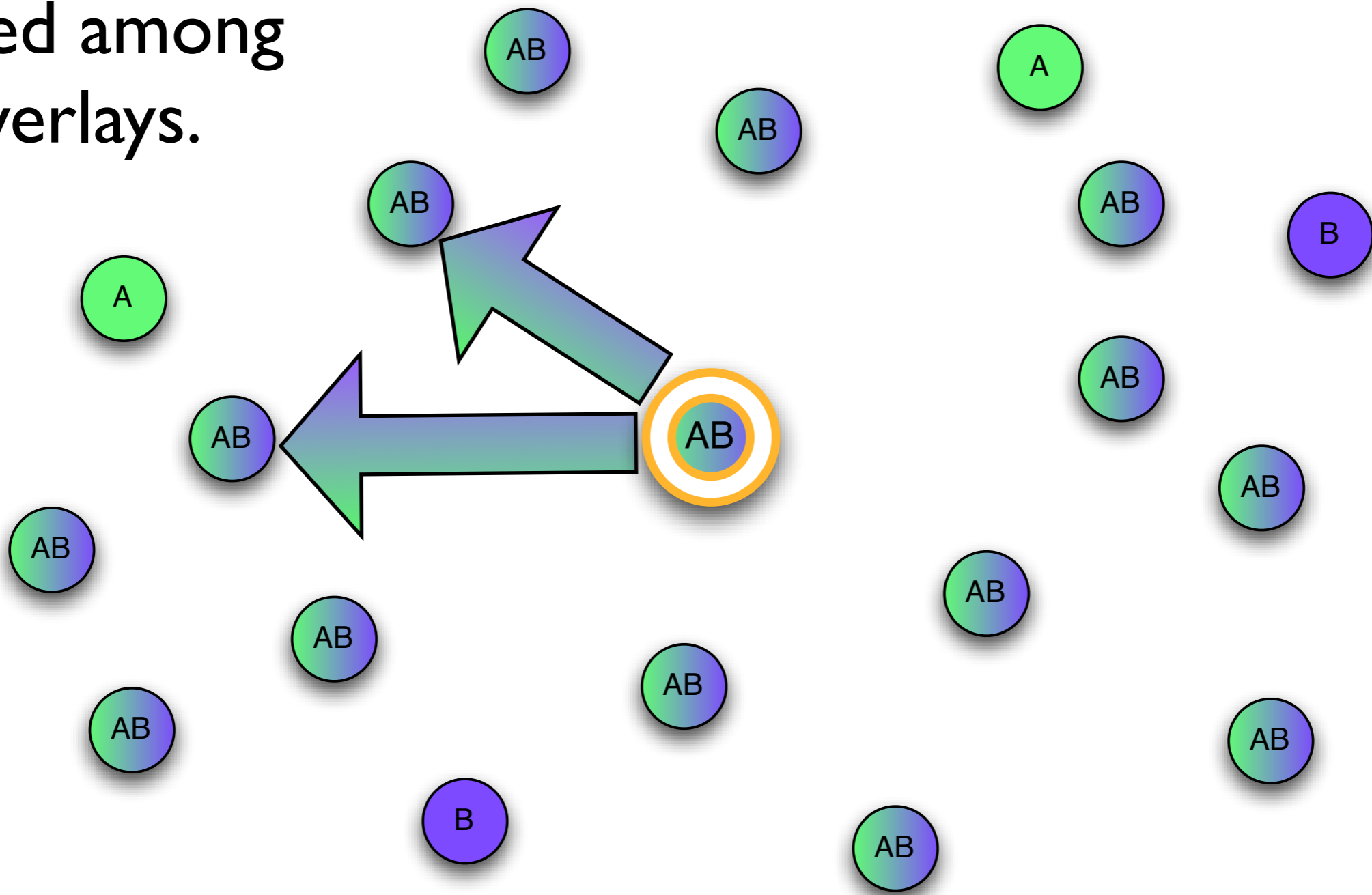
Low probability of choosing the same neighbor in different overlays





The final overlay

Links are shared among overlays.

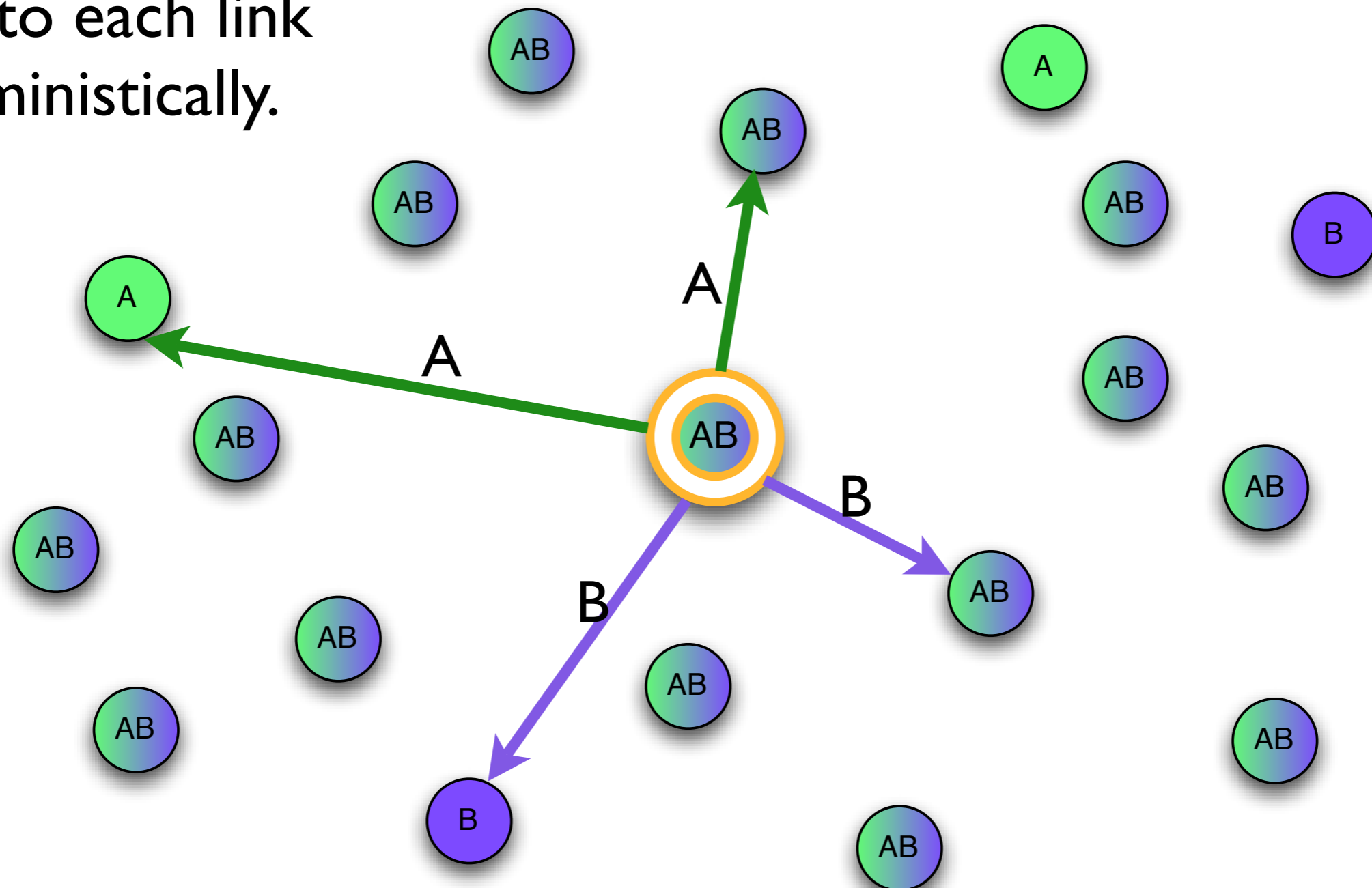




An example

Each node assigns a weight to each link deterministically.

$$w(id) = \text{Hash}(\text{string}(\text{myself}) + \text{string}(id))$$

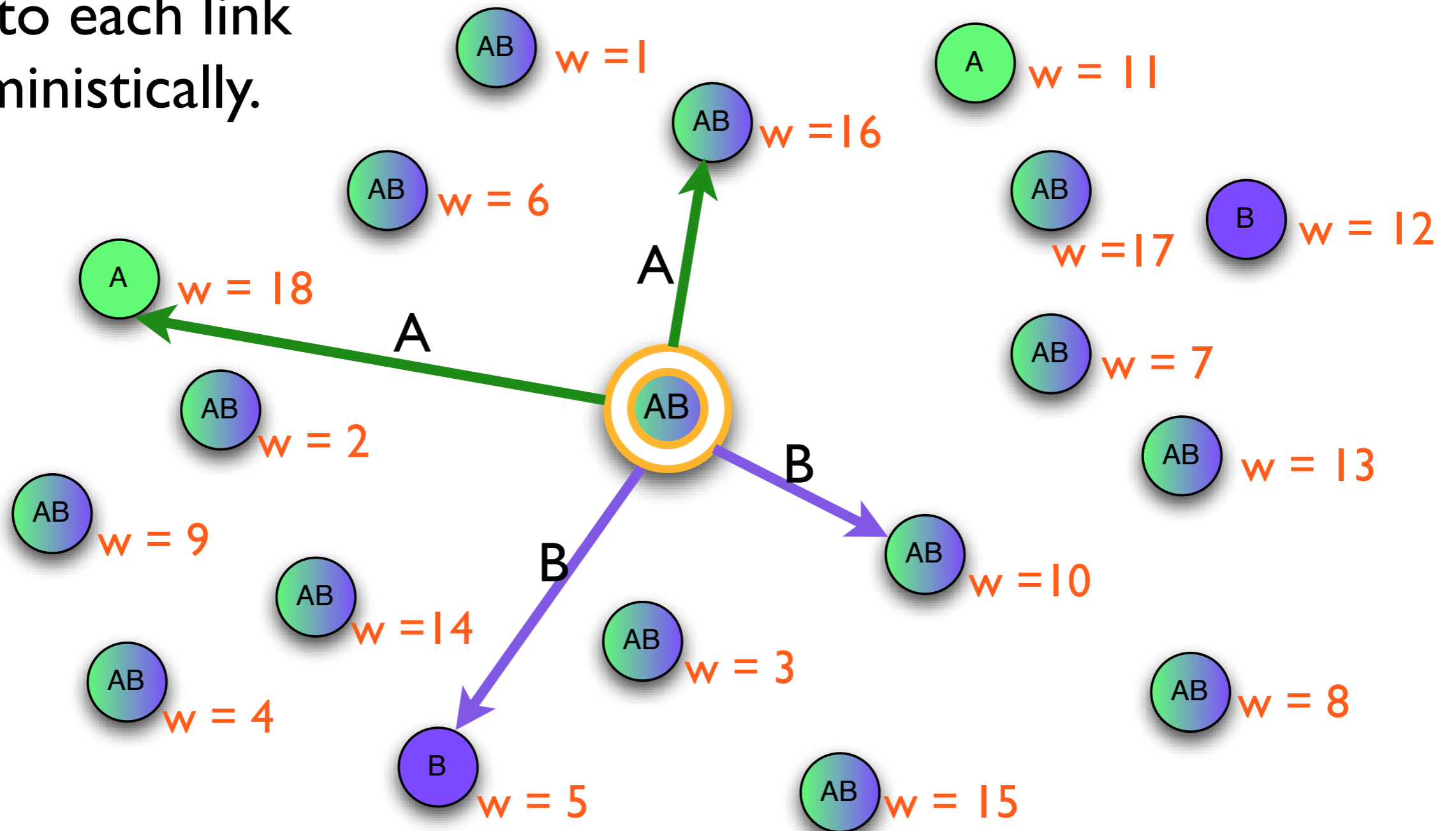




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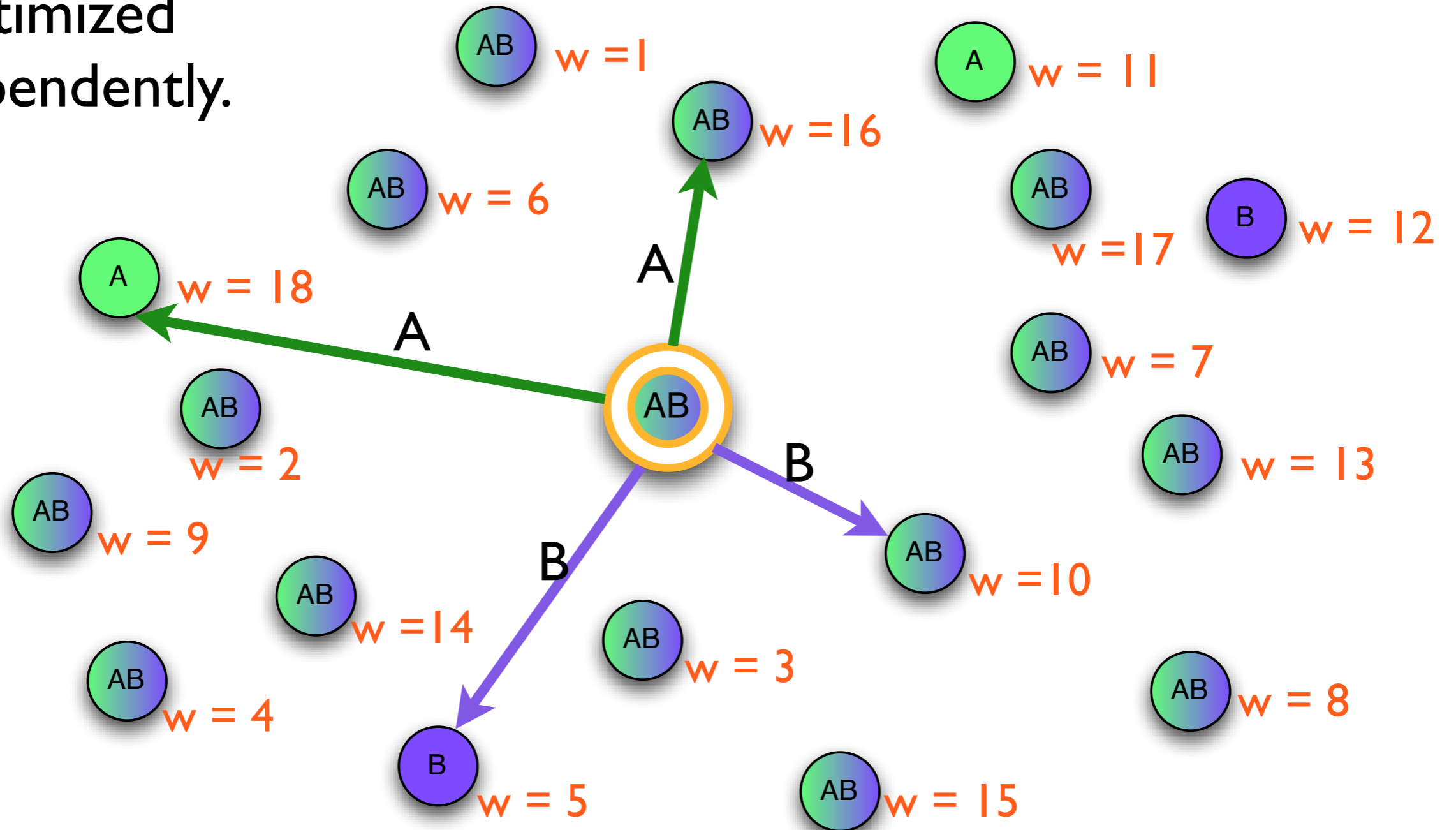




An example

Each overlay is optimized independently.

$$w(\text{id}) = \text{Hash}(\text{string}(\text{myself}) + \text{string}(\text{id}))$$

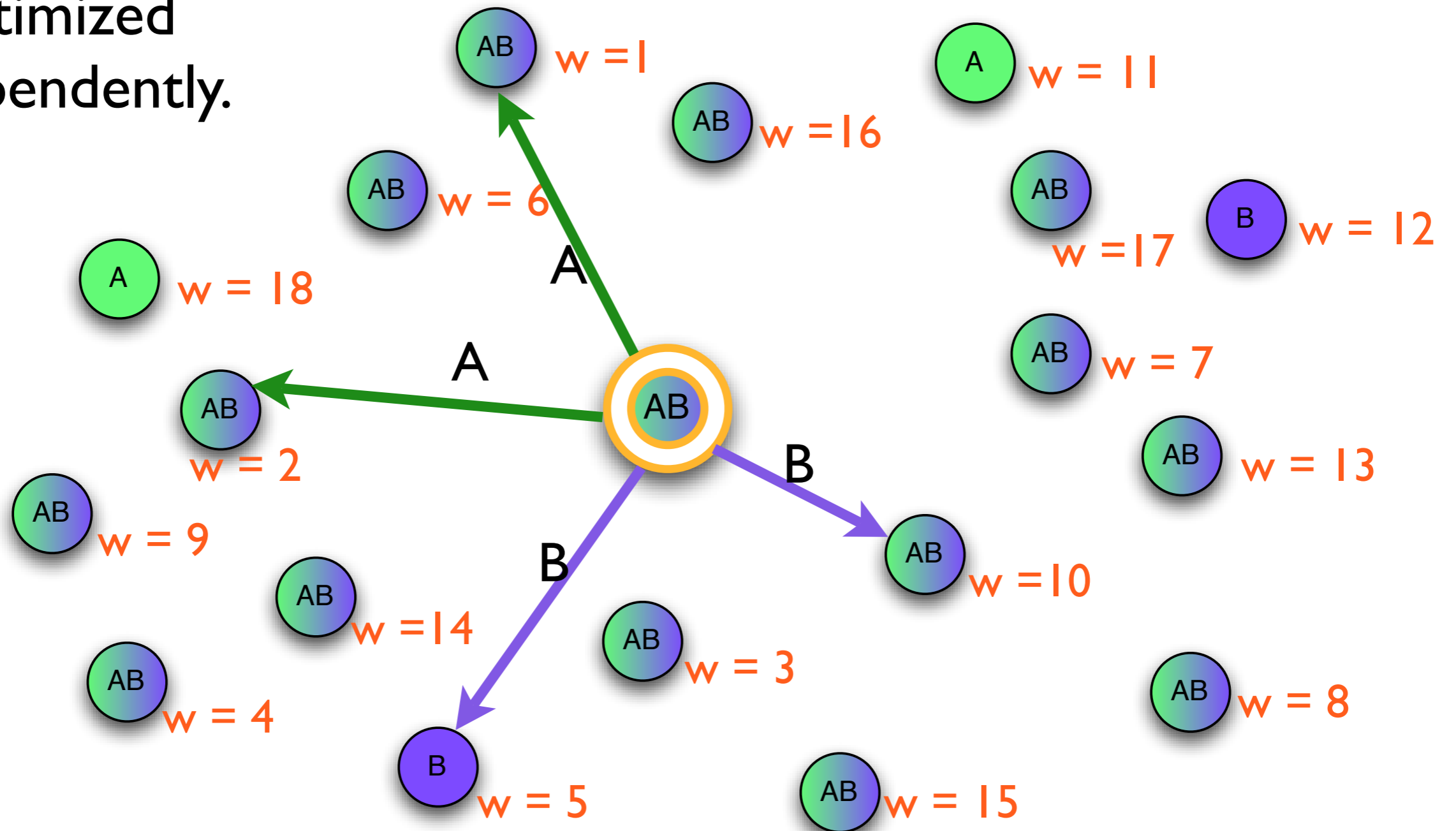




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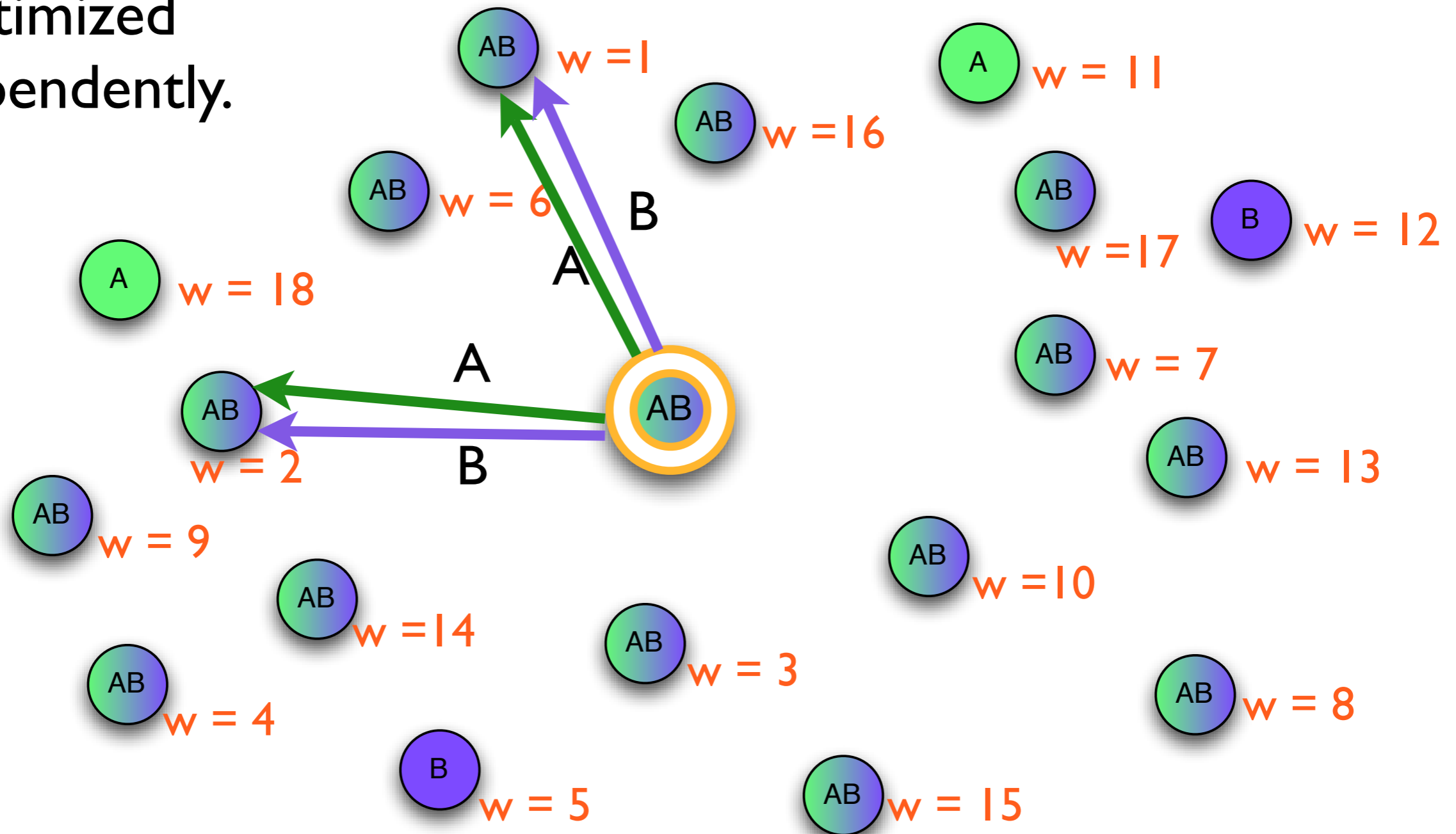




An example

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Weight assignment

$$w(\text{id}) = \text{Hash}(\text{string}(\text{myself}) + \text{string}(\text{id}))$$





Weight assignment


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Weight assignment

$$w(\text{id}) = \text{Hash}(\text{string}(\text{myself}) + \text{string}(\text{id}))$$


$$w = 2$$
$$w = 13$$


$$w = 54$$

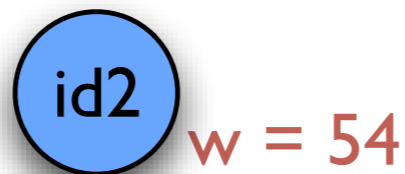
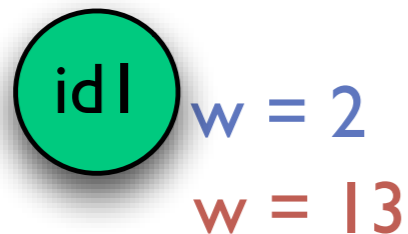

$$w = 4$$

Because of the confusion and diffusion properties of the hash function, nodes **id2** and **id3** will assign completely different weights to **id1**.



Weight assignment

$$w(\text{id}) = \text{Hash}(\text{string}(\text{myself}) + \text{string}(\text{id}))$$



Because of the confusion and diffusion properties of the hash function, nodes **id2** and **id3** will assign completely different weights to **id1**.

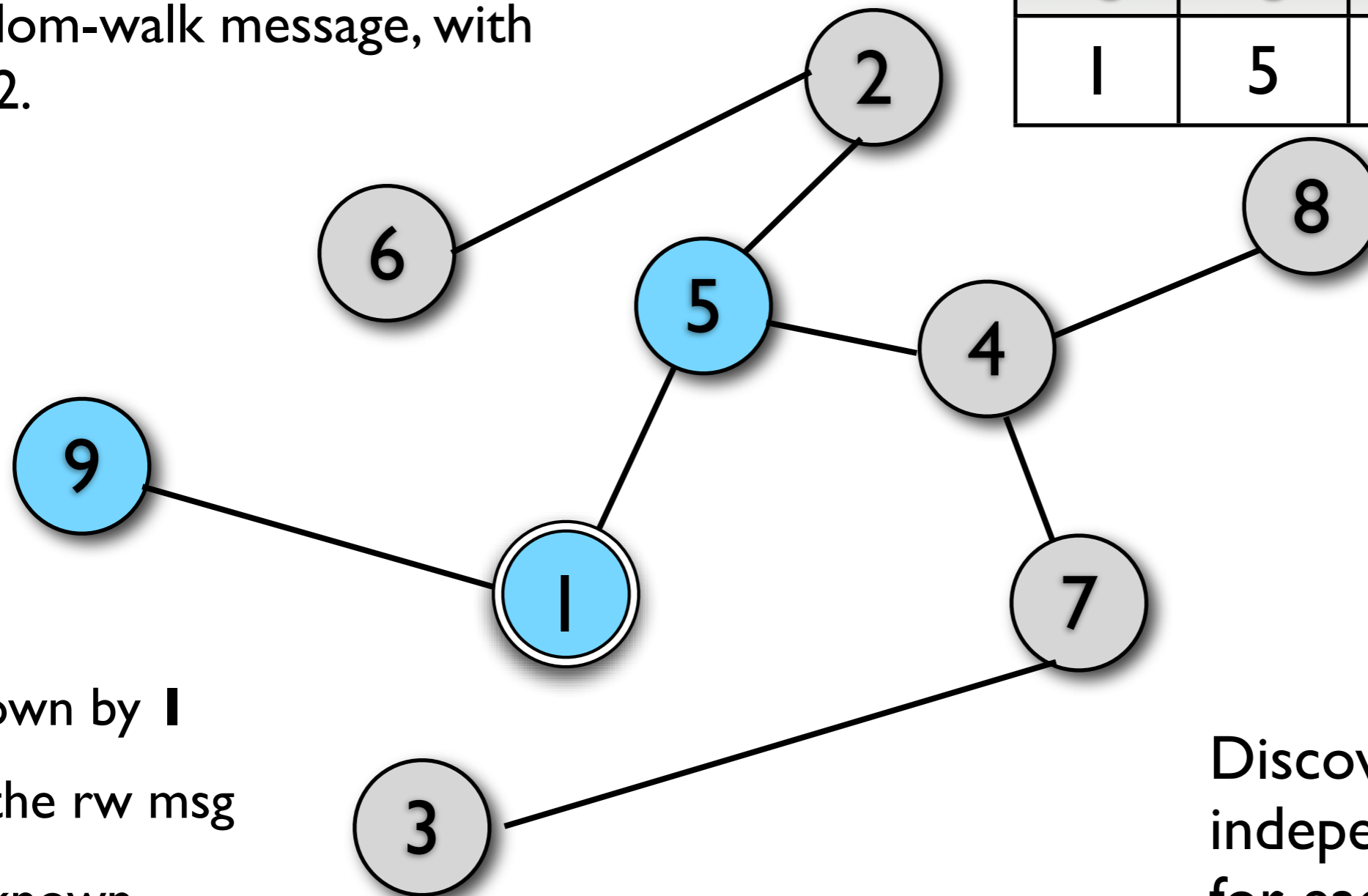
- Weight is independent of interests.
- Also, weight is not symmetric.
- Each node orders the node space uniquely and uniformly.
- This prevents StAN from inducing clustering in the physical overlay.



Node discovery

A node chooses one of its neighbors at random, and sends it a random-walk message, with TTL=2.

| origin | target | ids |
|--------|--------|-------|
| 1 | 5 | empty |



- known by 1
- in the rw msg
- unknown

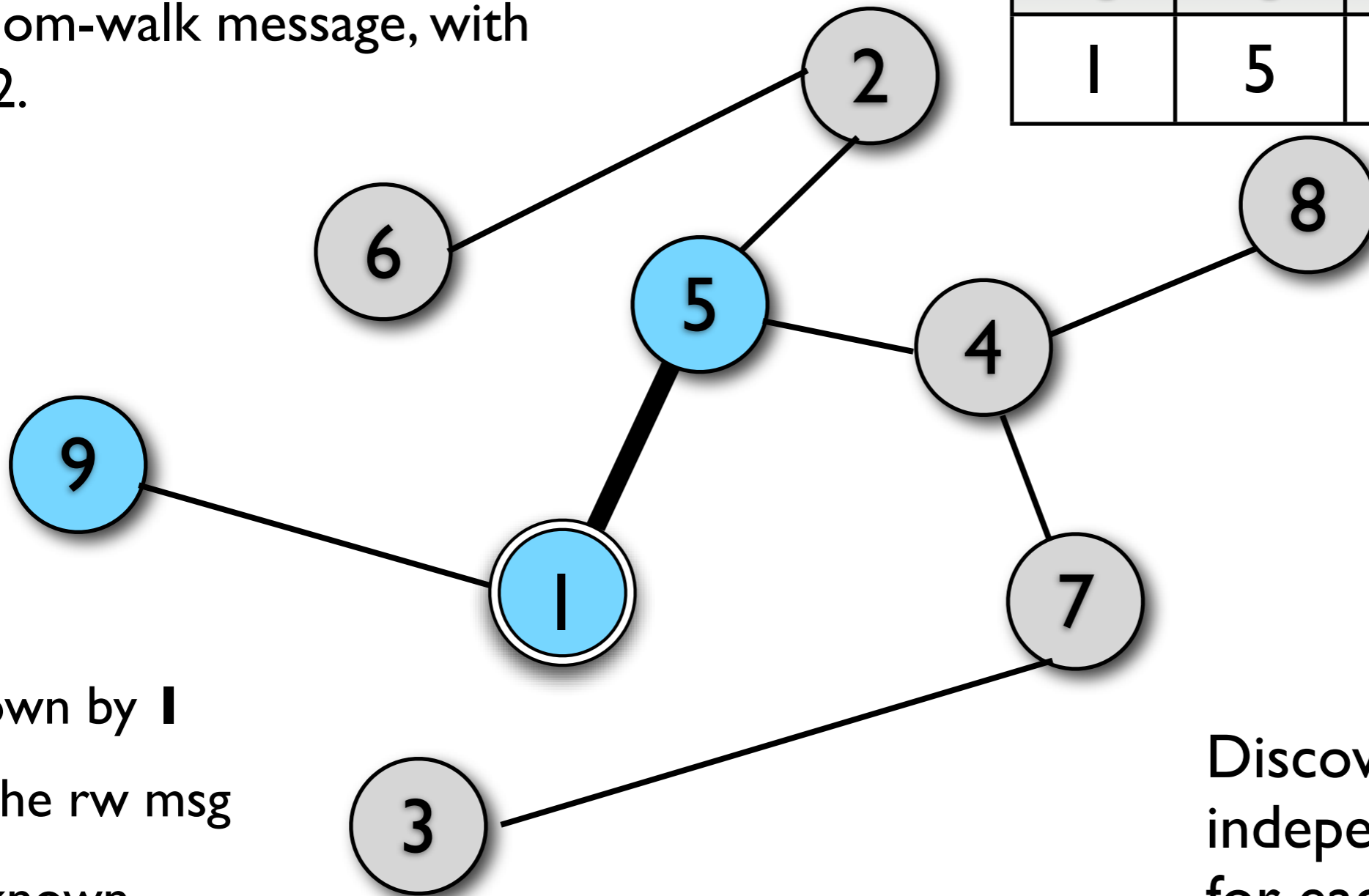
Discovery is done independently for each overlay.



Node discovery

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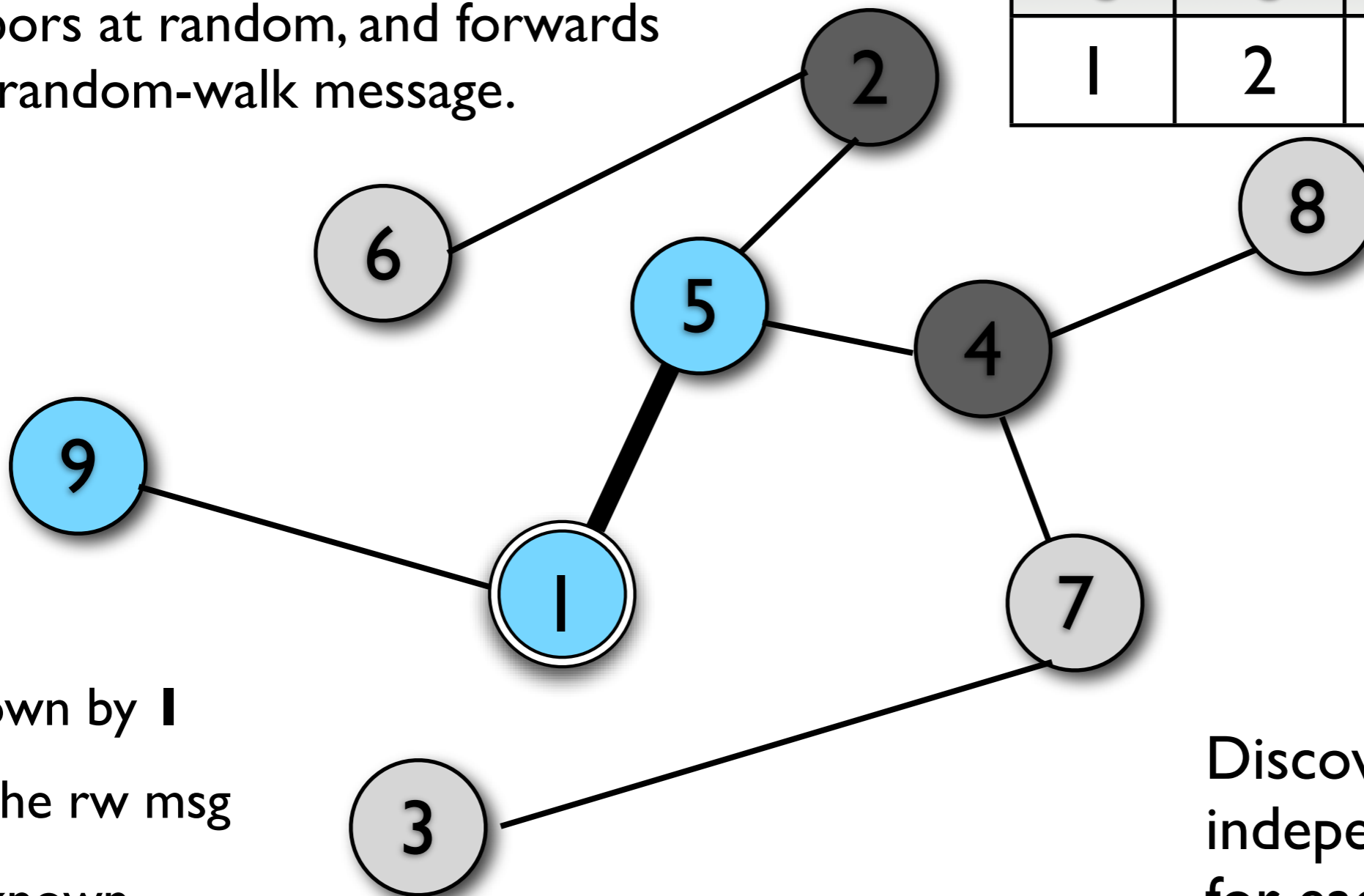


Node discovery

TTL=1

Now, **5** chooses one of its neighbors at random, and forwards it the random-walk message.

| origin | target | ids |
|--------|--------|---------|
| 1 | 2 | 5, 4, 2 |



- known by 1
- in the rw msg
- unknown

Discovery is done independently for each overlay.

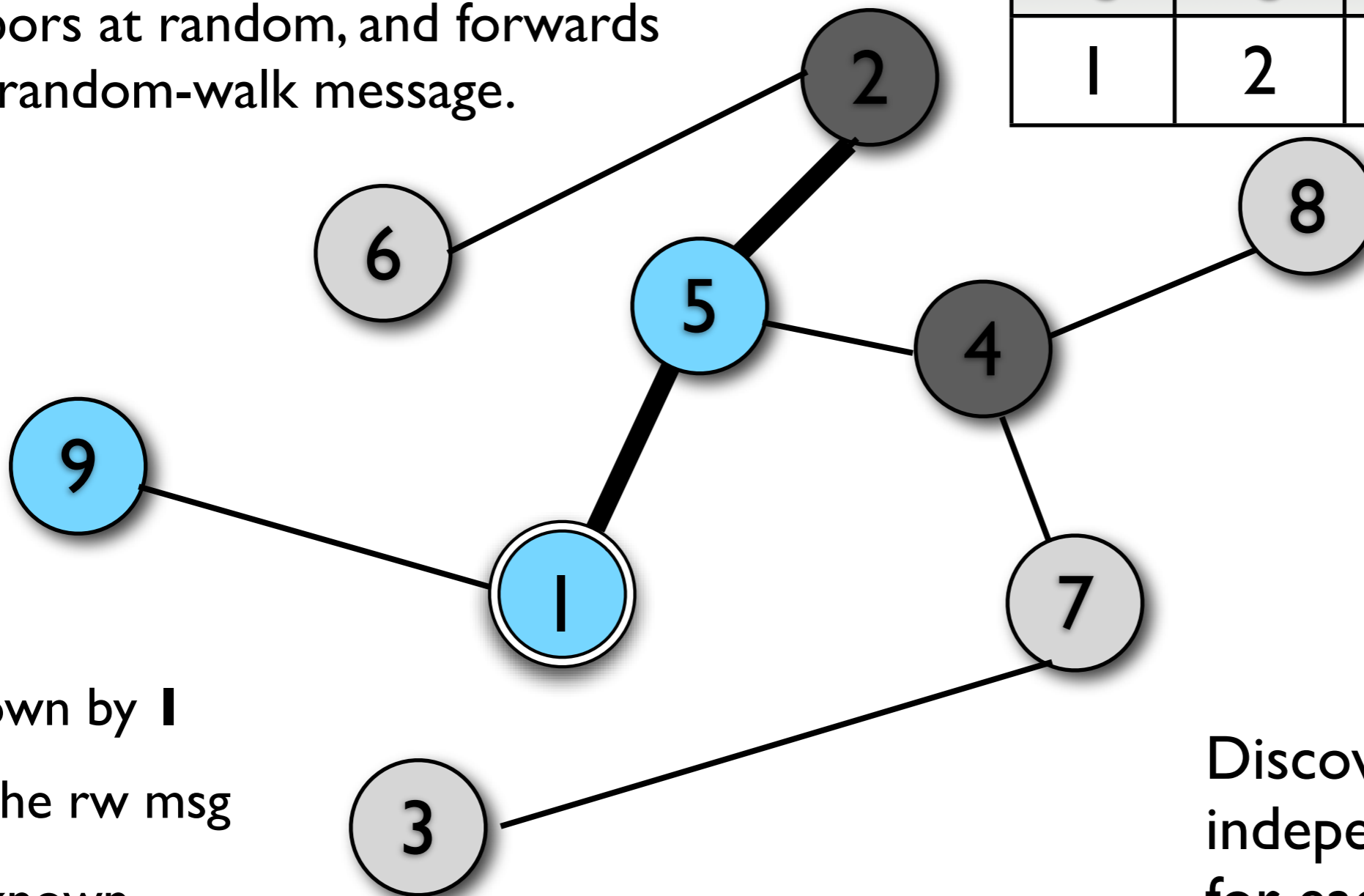


Node discovery

TTL=1

Now, **5** chooses one of its neighbors at random, and forwards it the random-walk message.

| origin | target | ids |
|--------|--------|---------|
| 1 | 2 | 5, 4, 2 |



- known by 1
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Discovery is done independently for each overlay.

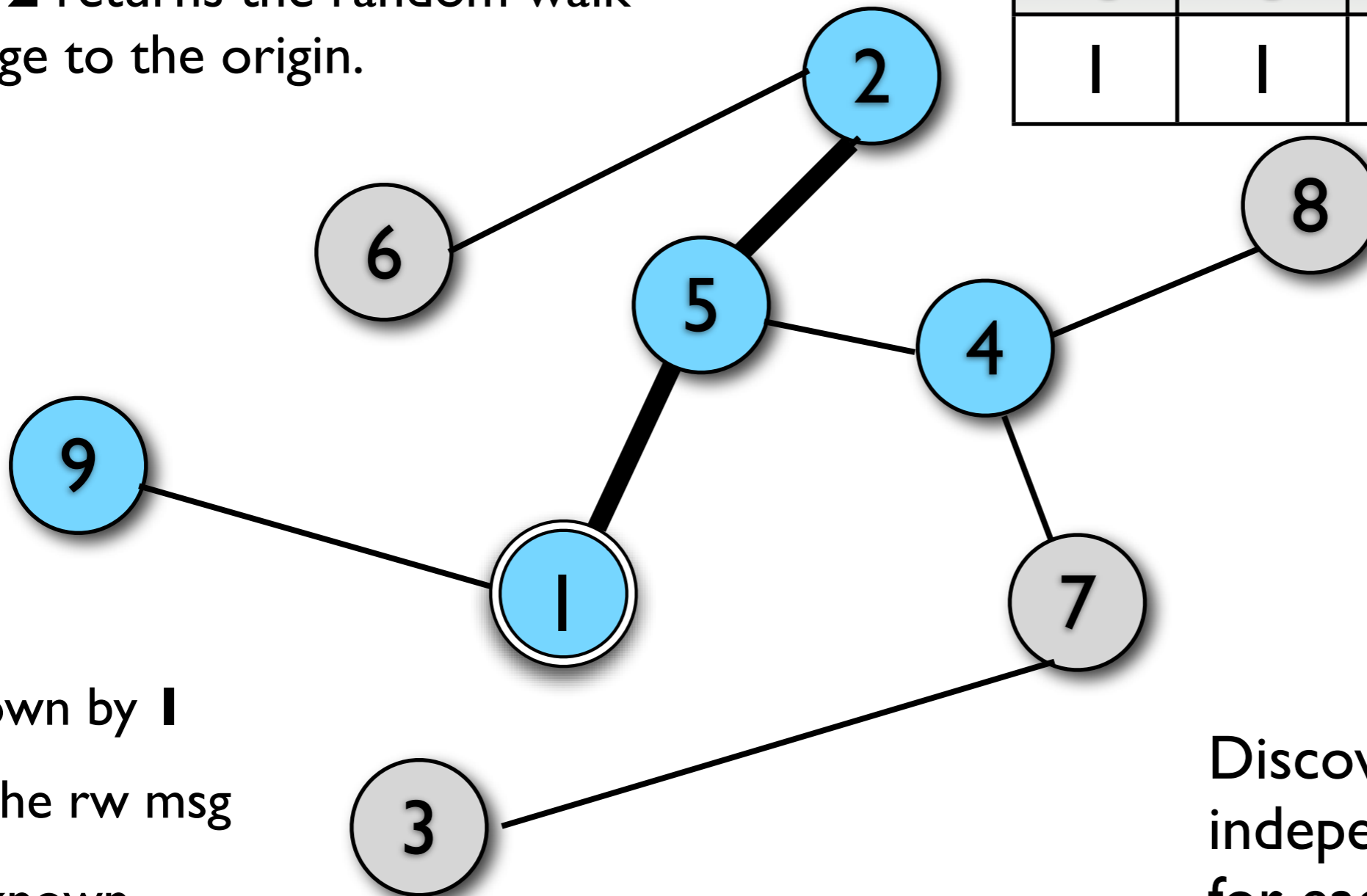


Node discovery

TTL=0

Node **2** returns the random walk message to the origin.

| origin | target | ids |
|--------|--------|---------|
| 1 | 1 | 5, 4, 2 |



- known by 1
- in the rw msg
- unknown

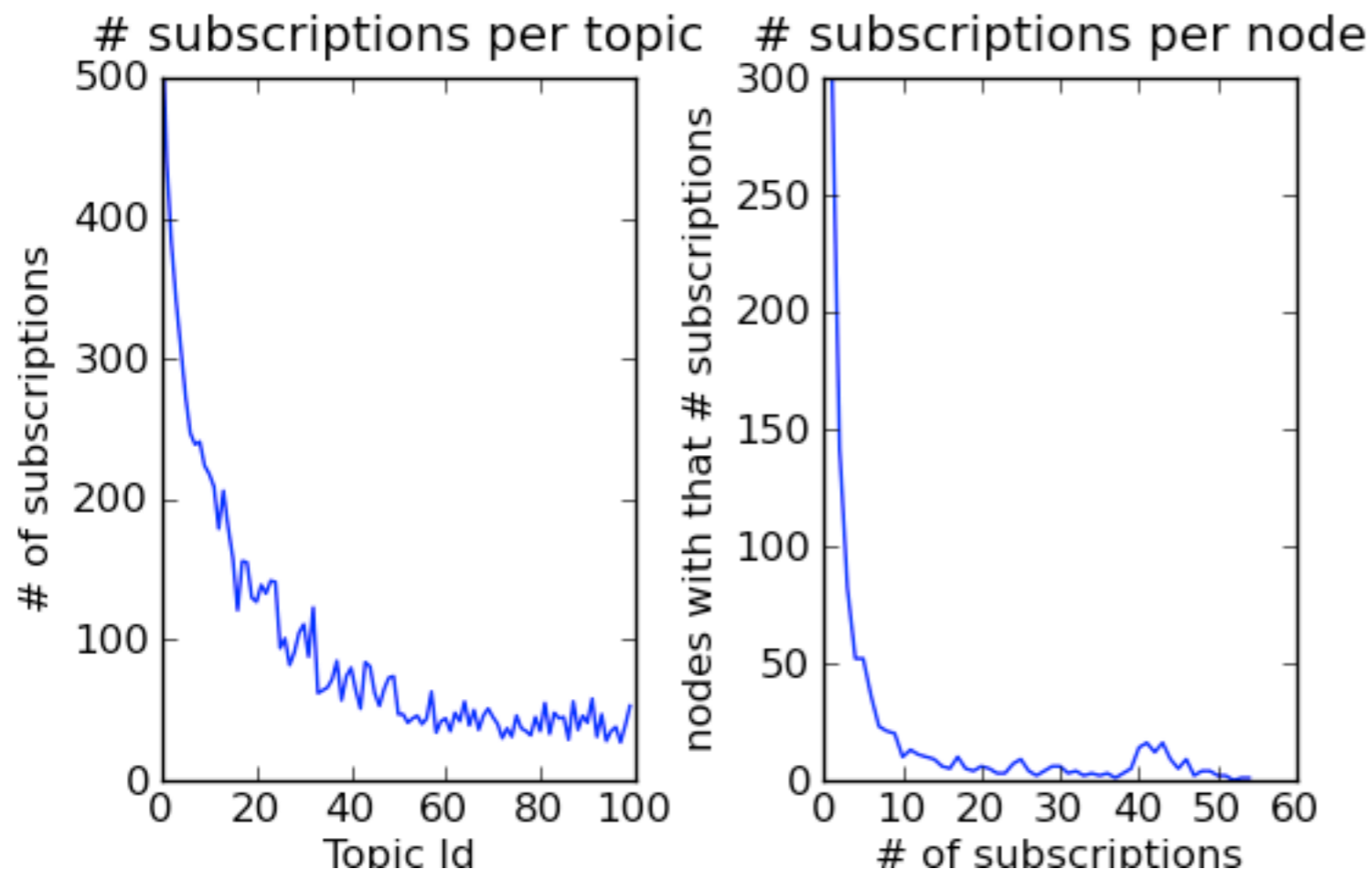
Discovery is done independently for each overlay.



Evaluation



Subscriptions



Subscriptions are correlated with a high level of confidence.

- Built a two-dimensional grid and randomly placed nodes and topics on it.
- Assigned an interest radius to nodes.
- Nodes are subscribed to topics within that radius.

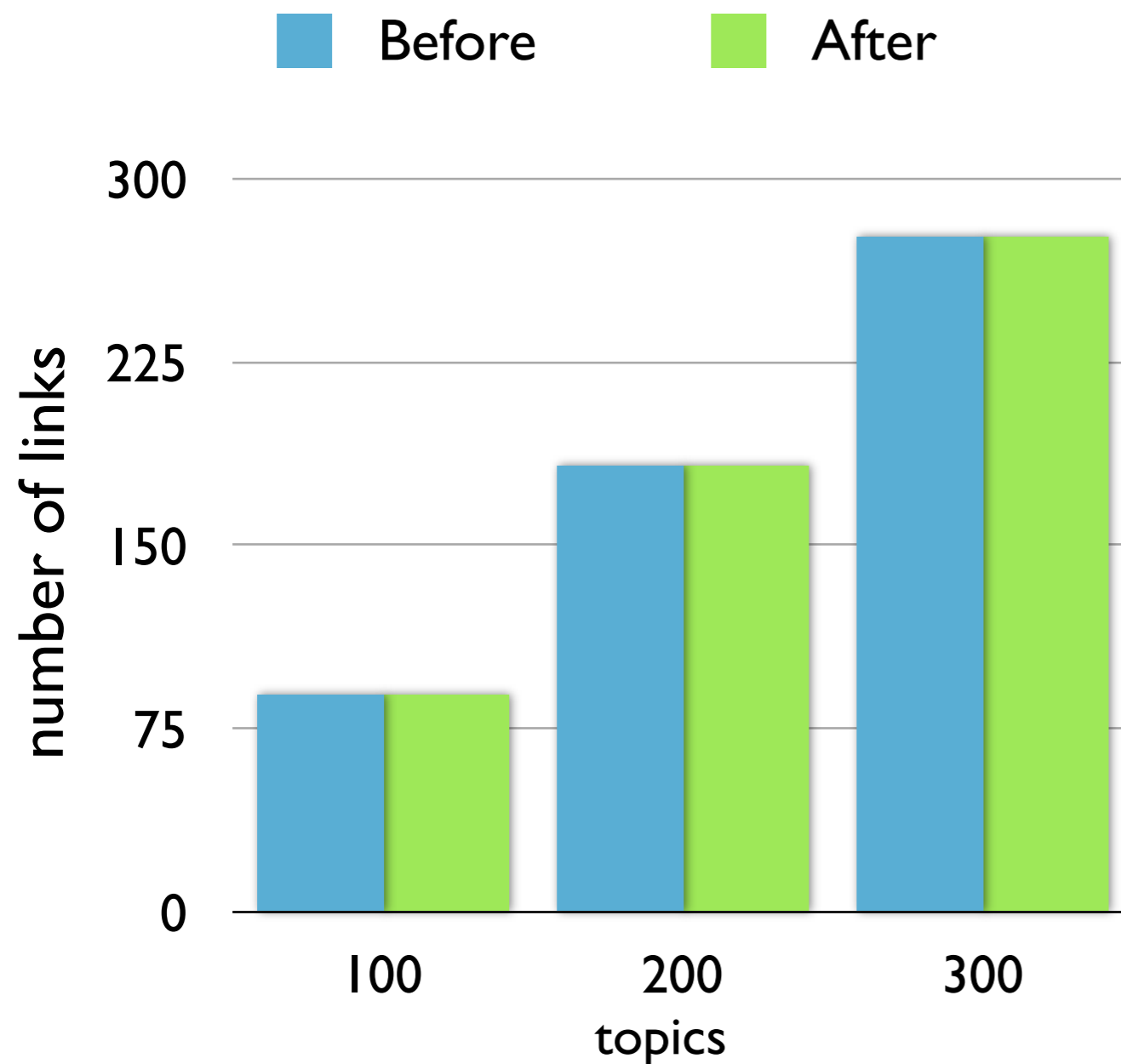


Simulation Setup

- Erdős–Rényi model
- Strongly connected
- Measurements:
 - physical link sharing
 - impact on overlay properties



View sizes



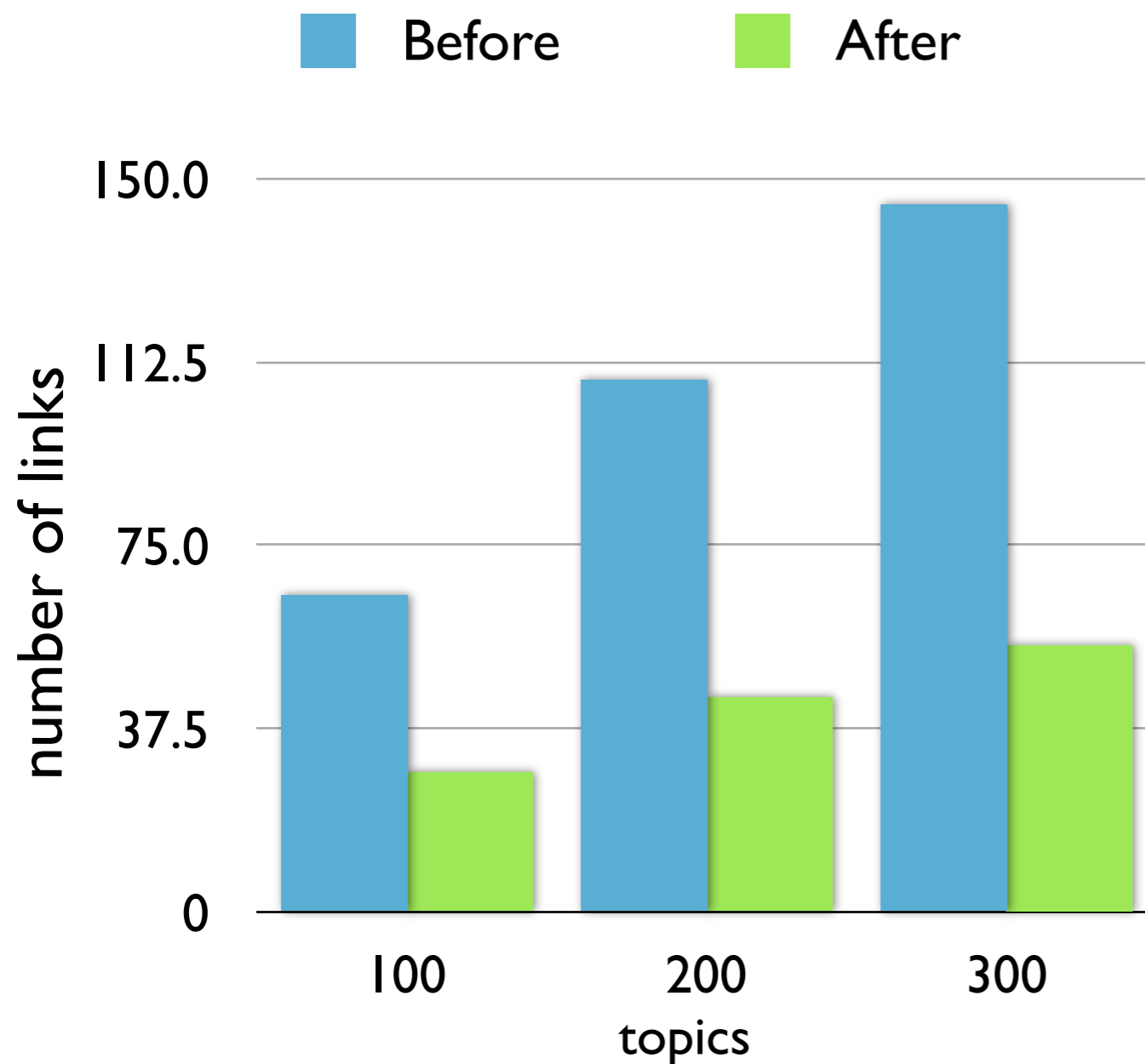
- StAN maintains the number of neighbors each node already has in each overlay.

resilience

Total number of logical links for 1000 nodes.



View sizes



- The number of physical links necessary to maintain the overlay is significantly reduced.

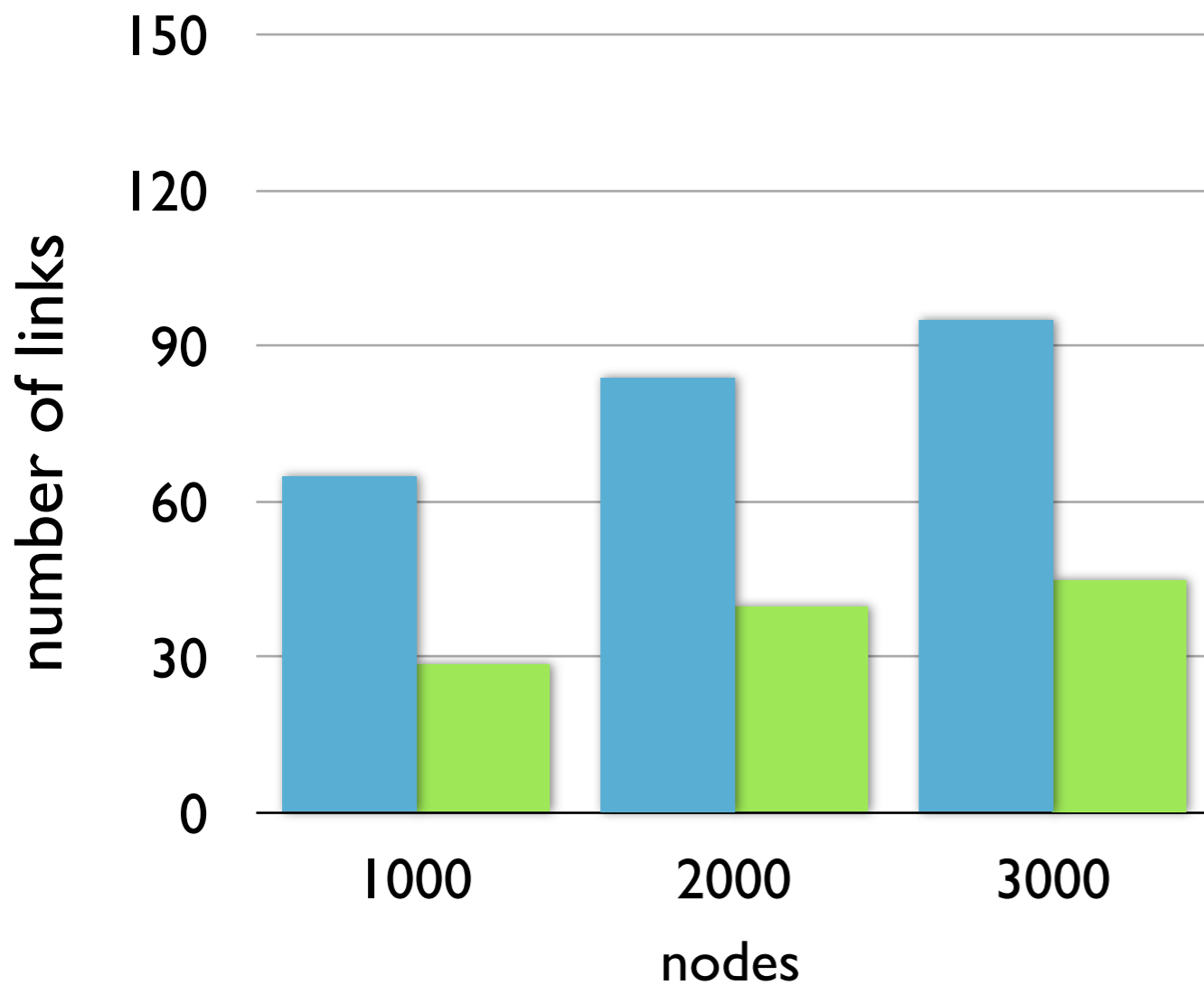
scalability

Unique (physical) links for 1000 nodes.

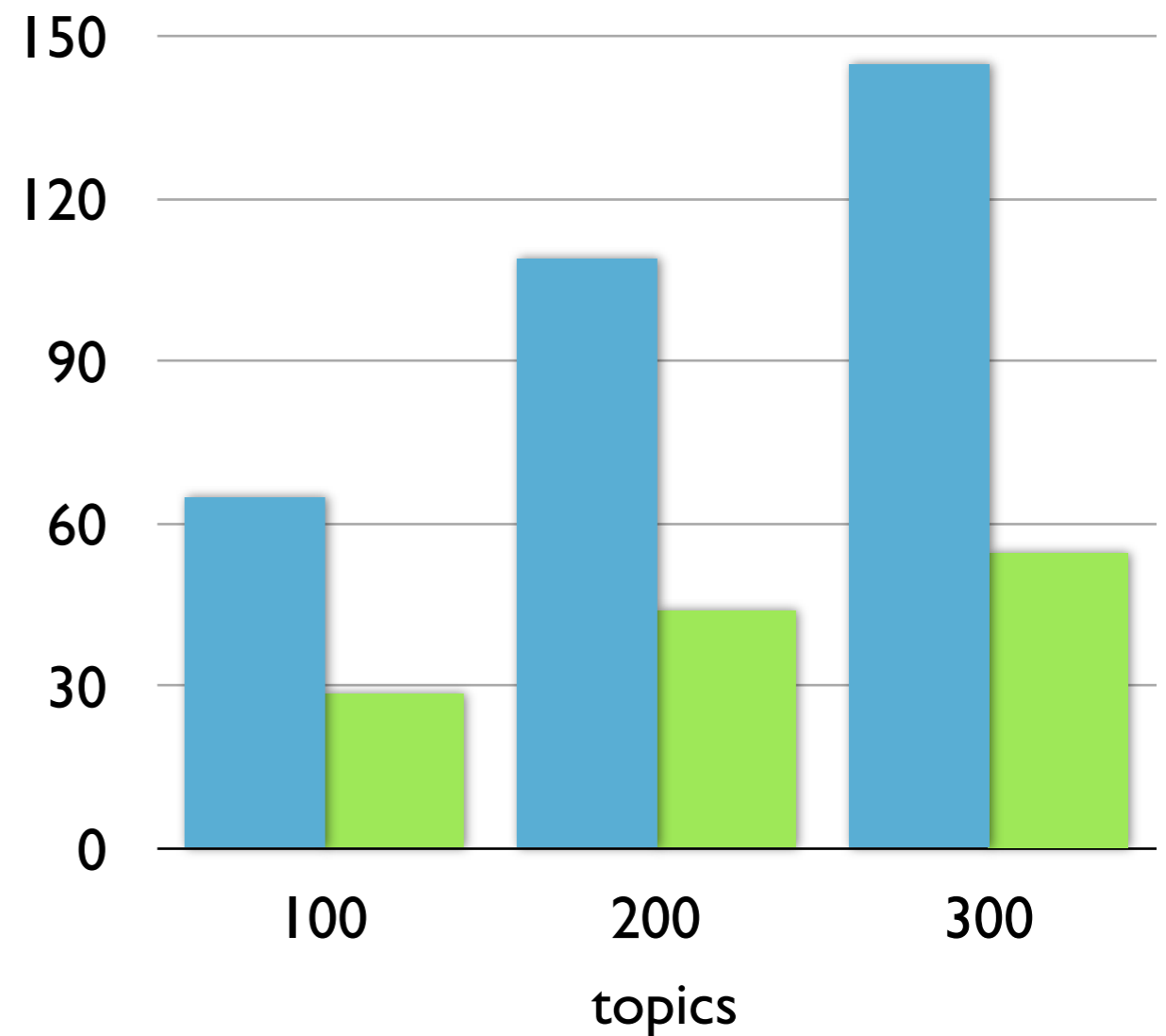


View sizes

Before After



Before After



Unique (physical) links for 100 topics₂₃

Unique (physical) links for 1000 nodes.



Physical overlay properties

| Measure | Before | After |
|------------------------|--------|-------|
| Clustering Coefficient | 0.50 | 0.13 |
| Diameter | 3 | 4 |

1000 nodes, 100 topics

- Clustering:
 - decreases as the number of links decreases
 - the increase induced by link sharing is mitigated by uniformity



Physical overlay properties

| Measure | Before | After |
|------------------------|--------|-------|
| Clustering Coefficient | 0.50 | 0.13 |
| Diameter | 3 | 4 |

- Diameter:
- there is a small increase due to the reduction of physical links.

1000 nodes, 100 topics



Summary

- StAN is the first protocol, to attempt to optimize pre-existent overlays in terms of physical links, by exploiting shared interests, but without actually disclosing them.
- It's a very simple protocol, yet surprisingly efficient.



Future Work

- We are currently applying StAN within NeEM, a gossip-based protocol, to experimentally evaluate its scalability in both:
 - the number of topics in the system
 - the number of topics subscribed to by each node



Questions?