Shuffling with a Croupier: Nat-Aware Peer-Sampling

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Introduction

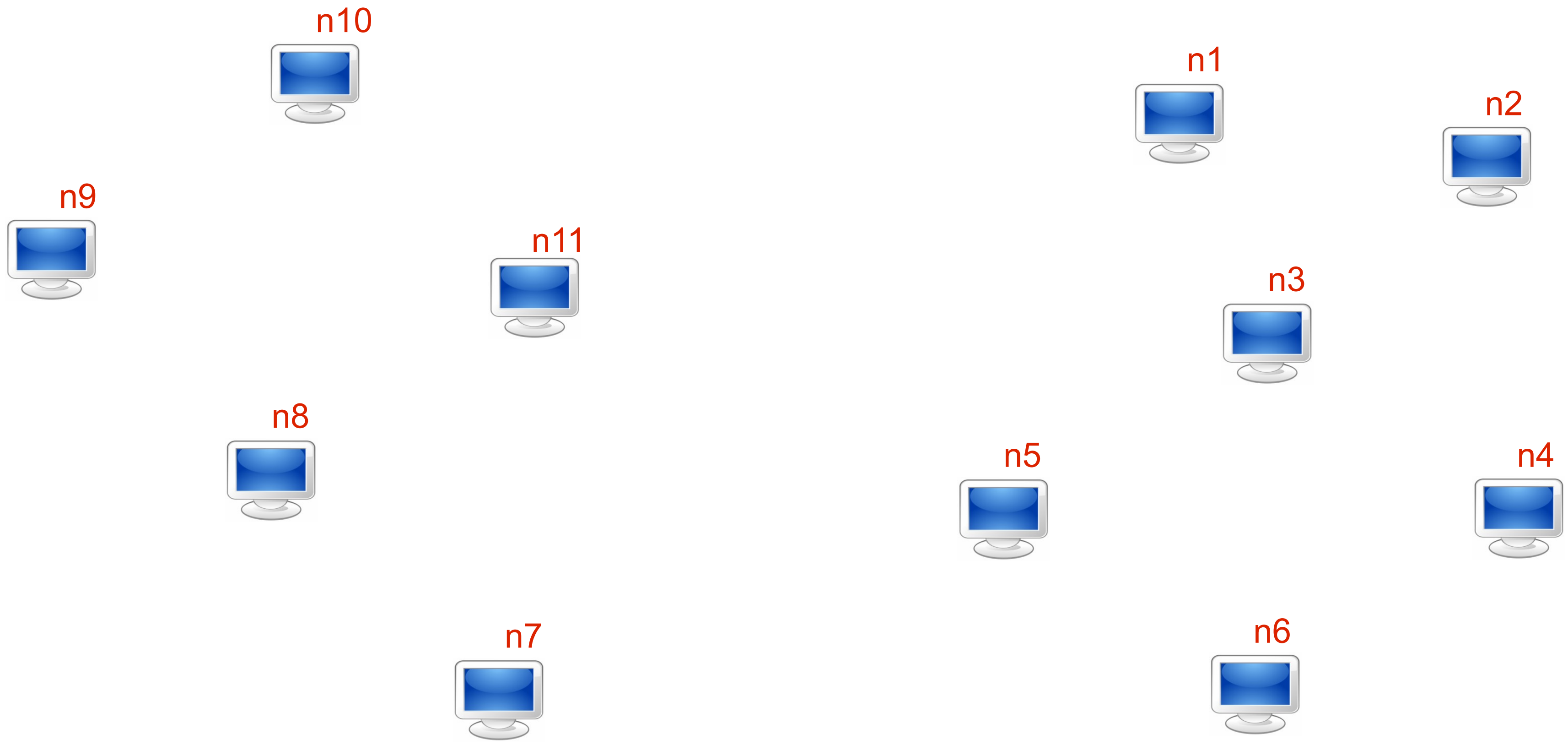
Gossip-based Protocols

- Gossip-based protocols have been widely used in large scale distributed applications.
  - Information dissemination
  - Aggregation
  - Overlay topology management

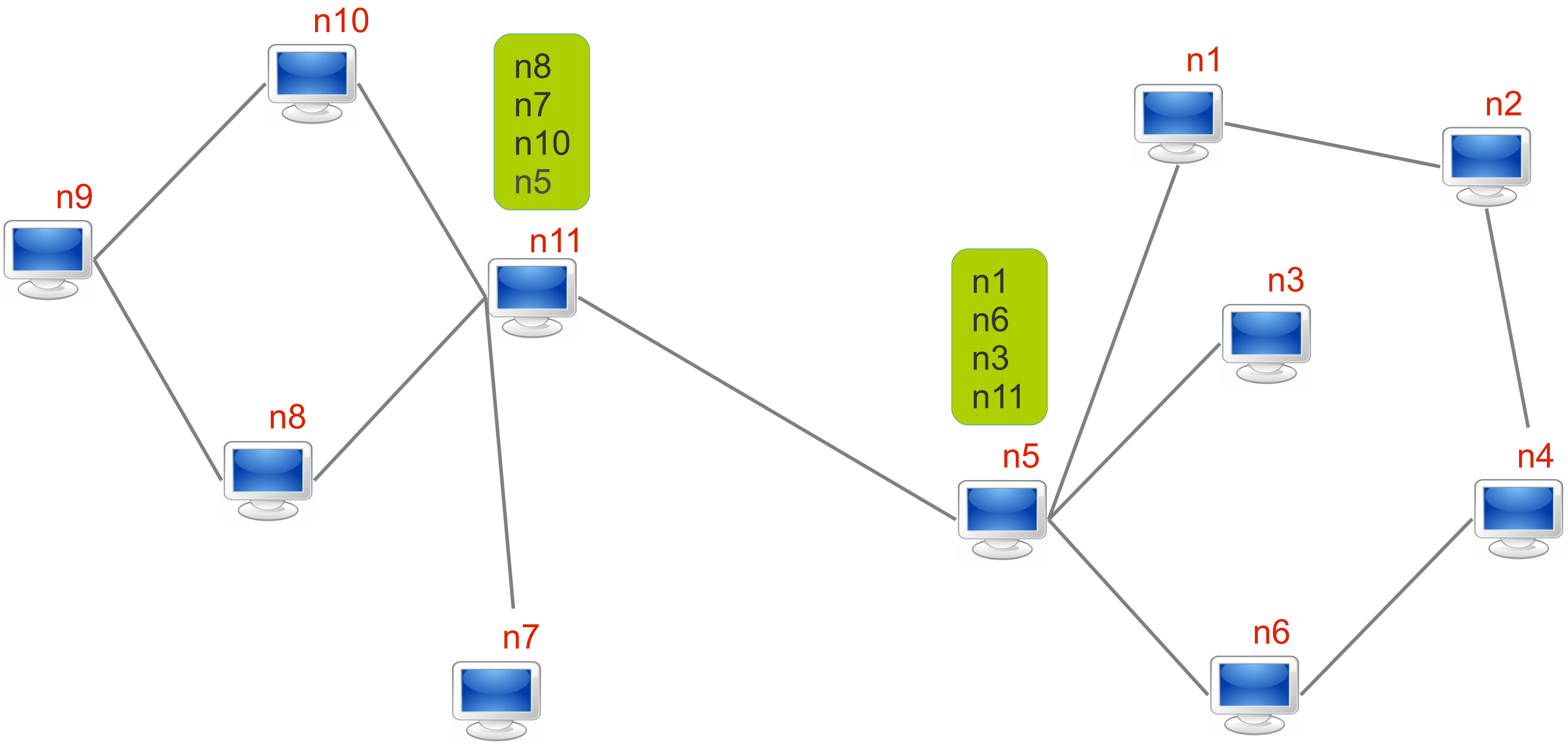
Why Peer Sampling?

- In a gossip-based protocol, each node periodically exchanges information with a random peer.
- Ideally, the peers should be selected uniformly at random.
- If a node could maintain a complete view, then uniform random selection would be easy, but this is not scalable.
- If each node has a small view, how can we achieve uniform randomness? peer sampling

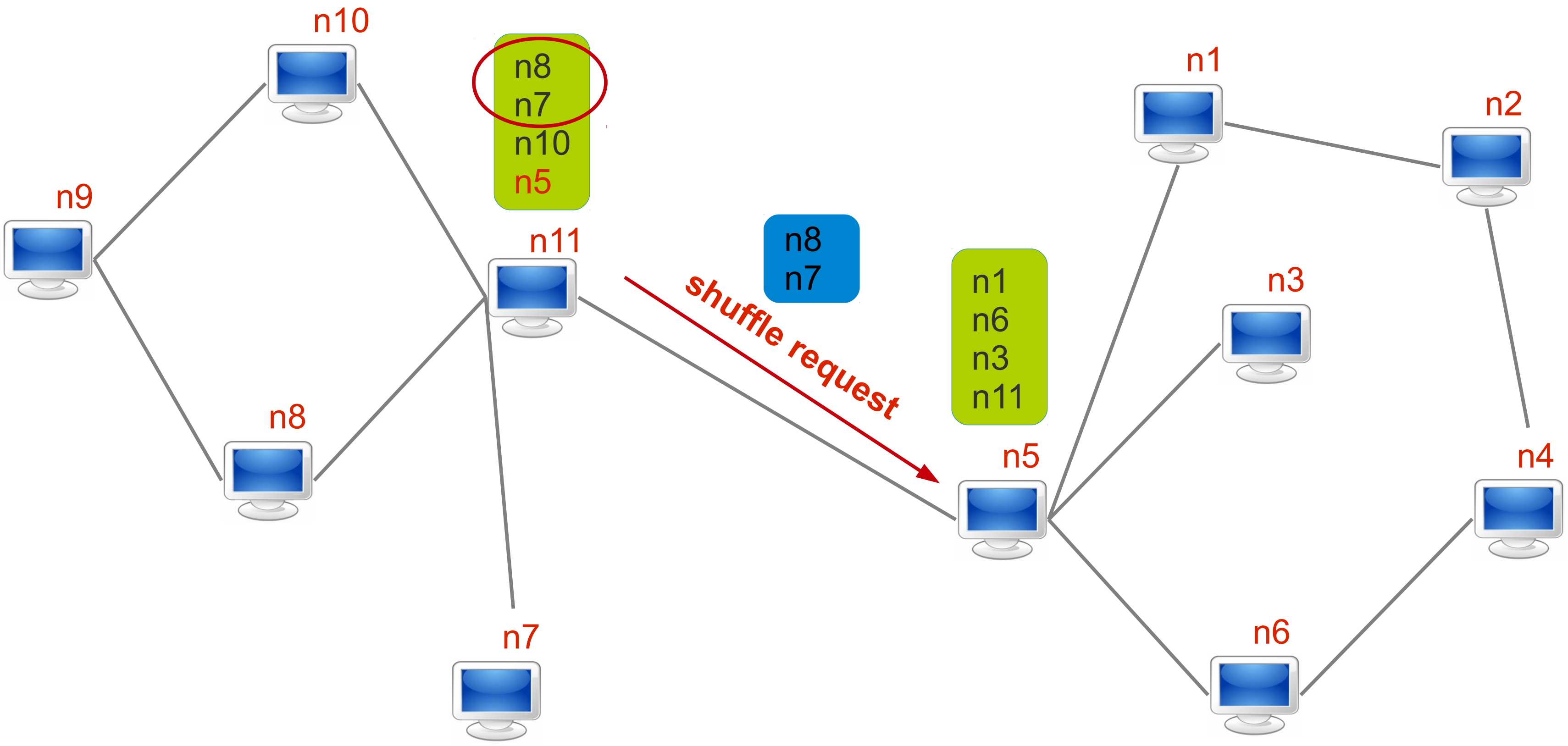
Gossip-based Peer Sampling Protocol (1/7)



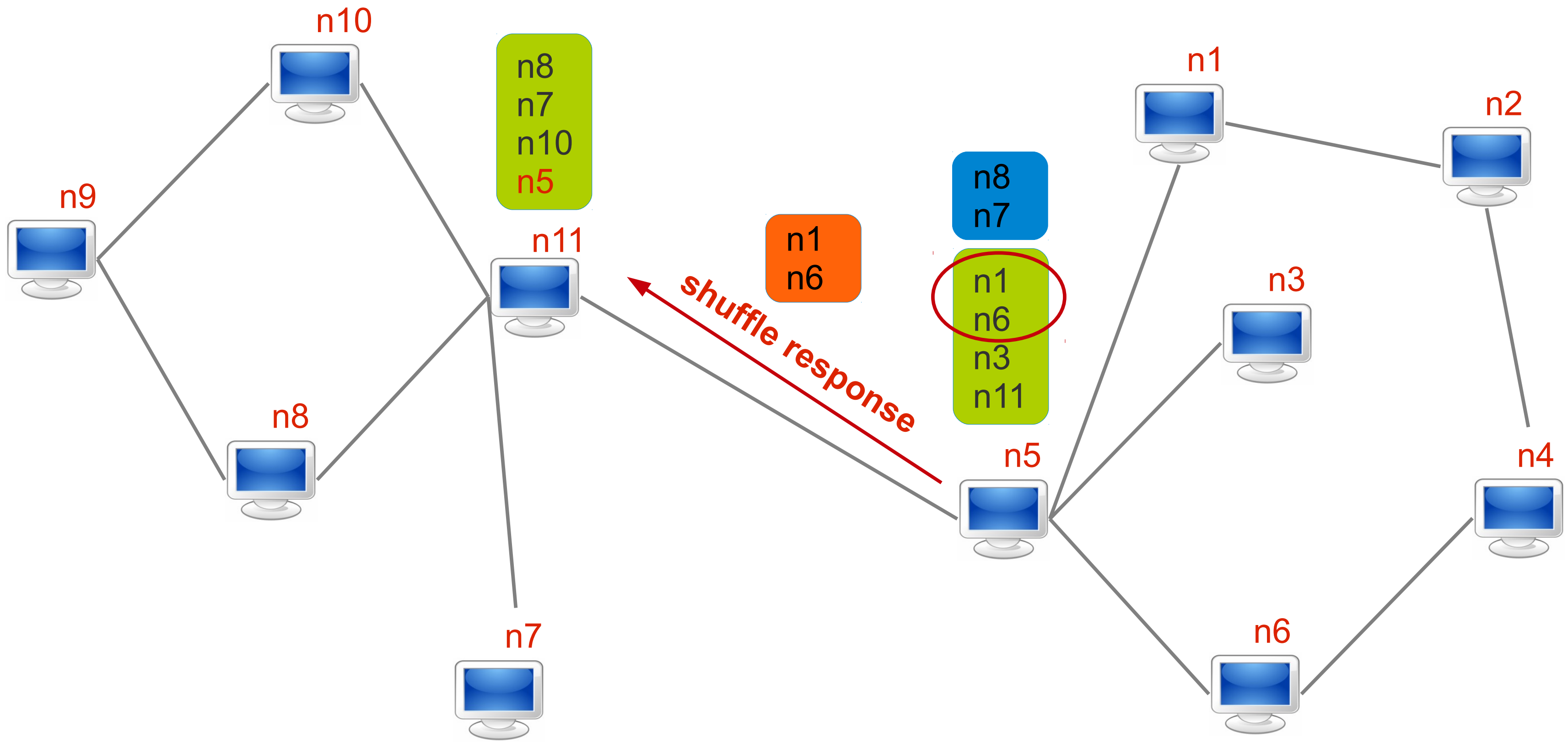
Gossip-based Peer Sampling Protocol (2/7)



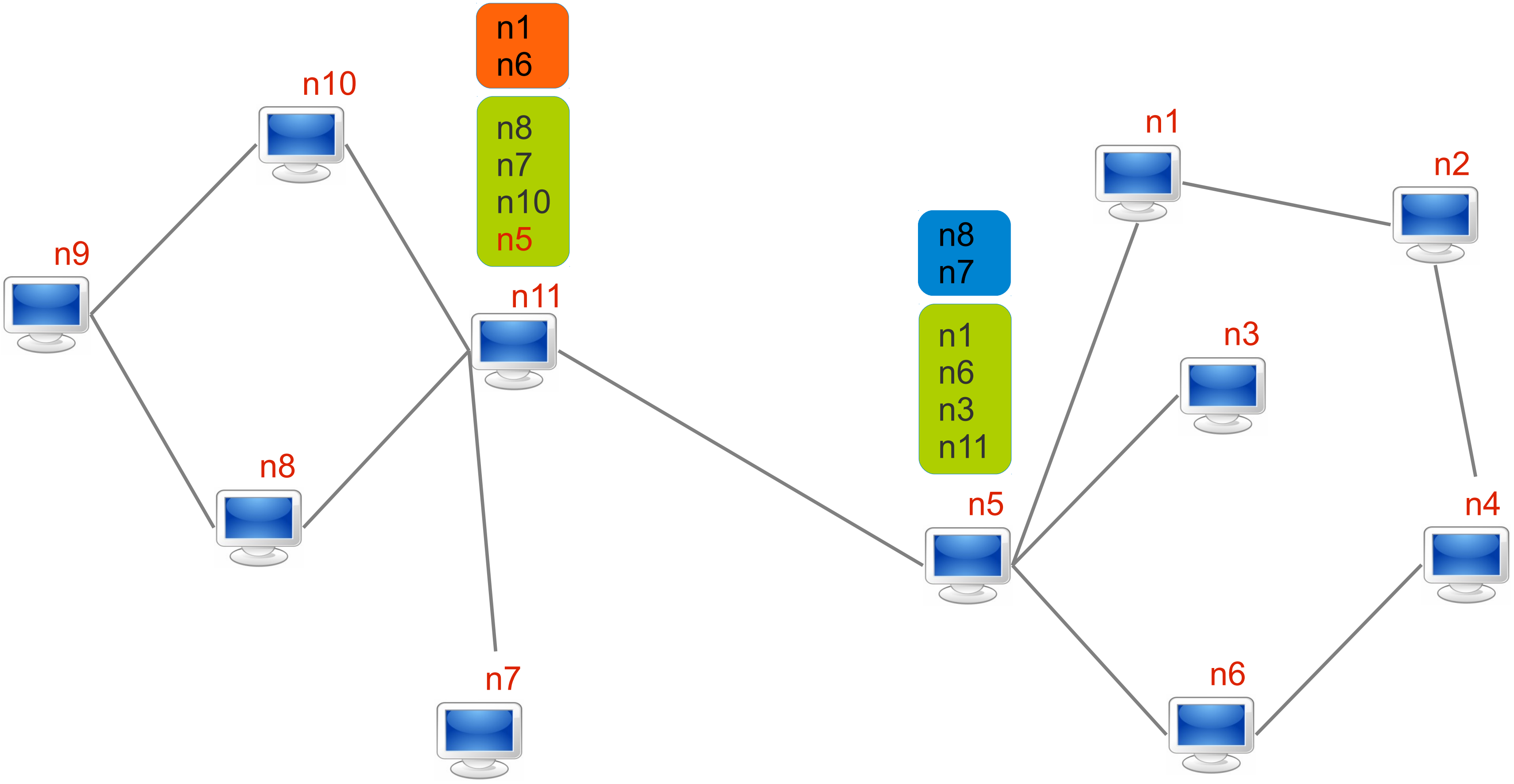
Gossip-based Peer Sampling Protocol (3/7)



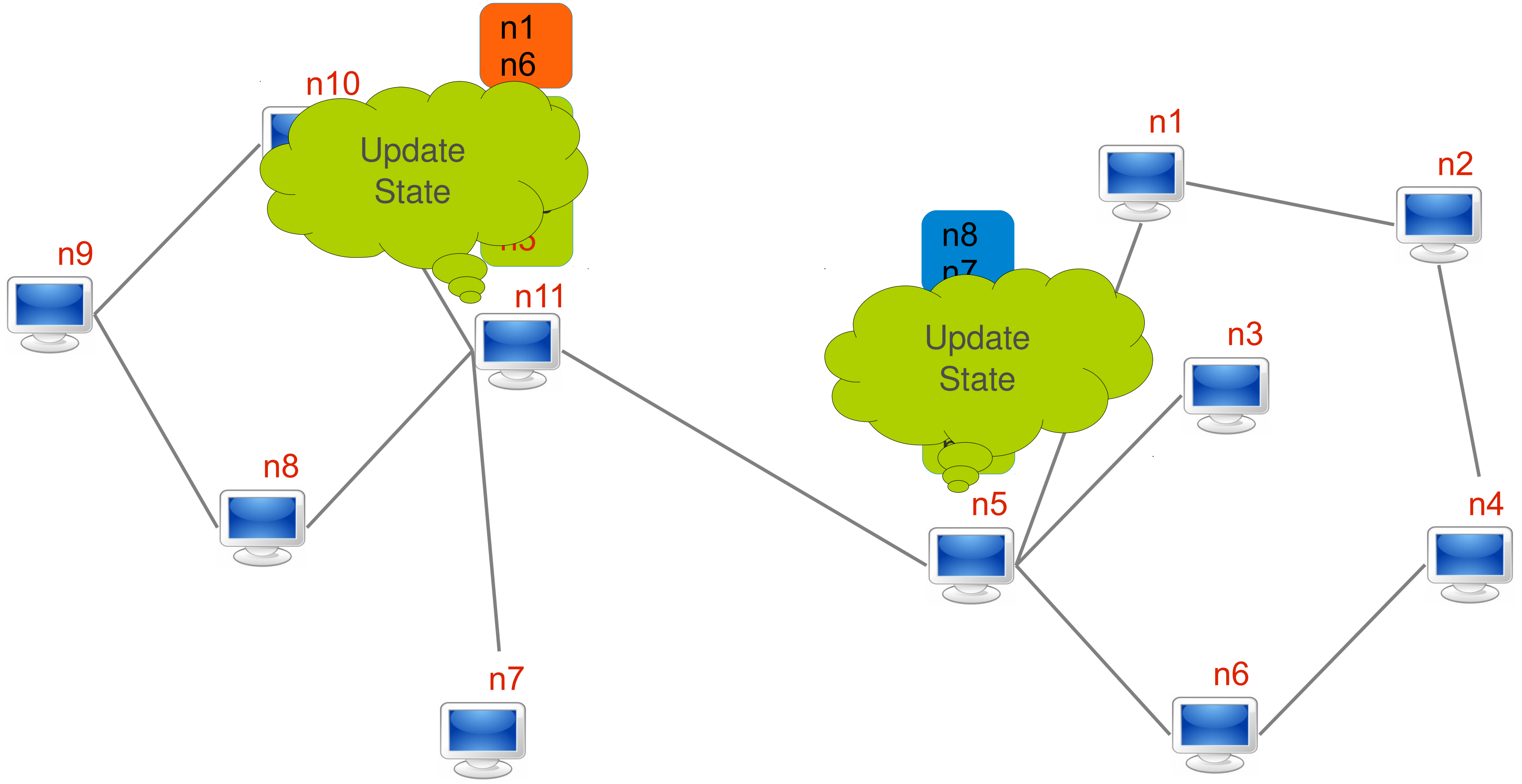
Gossip-based Peer Sampling Protocol (4/7)



Gossip-based Peer Sampling Protocol (5/7)



Gossip-based Peer Sampling Protocol (6/7)



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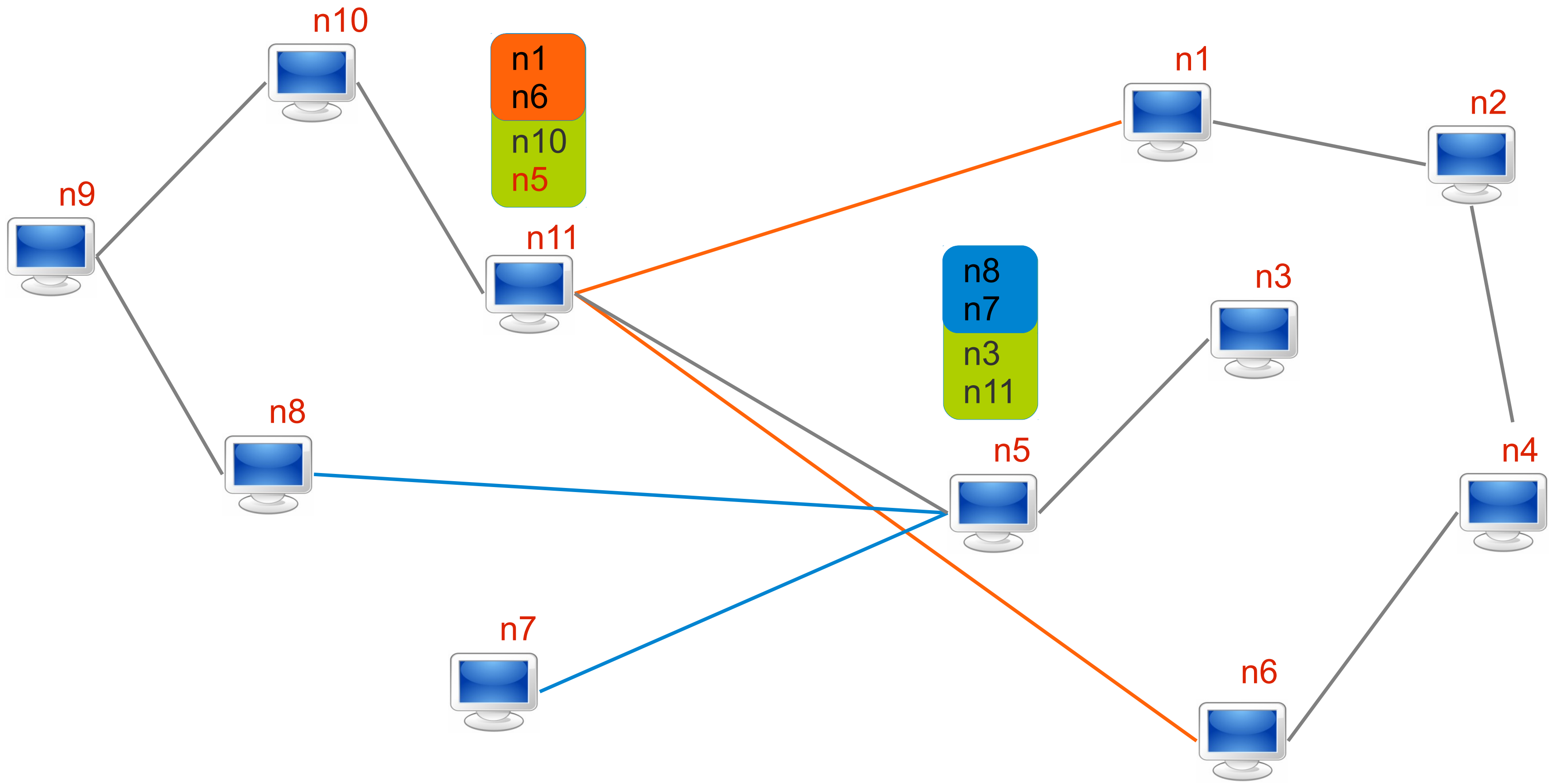
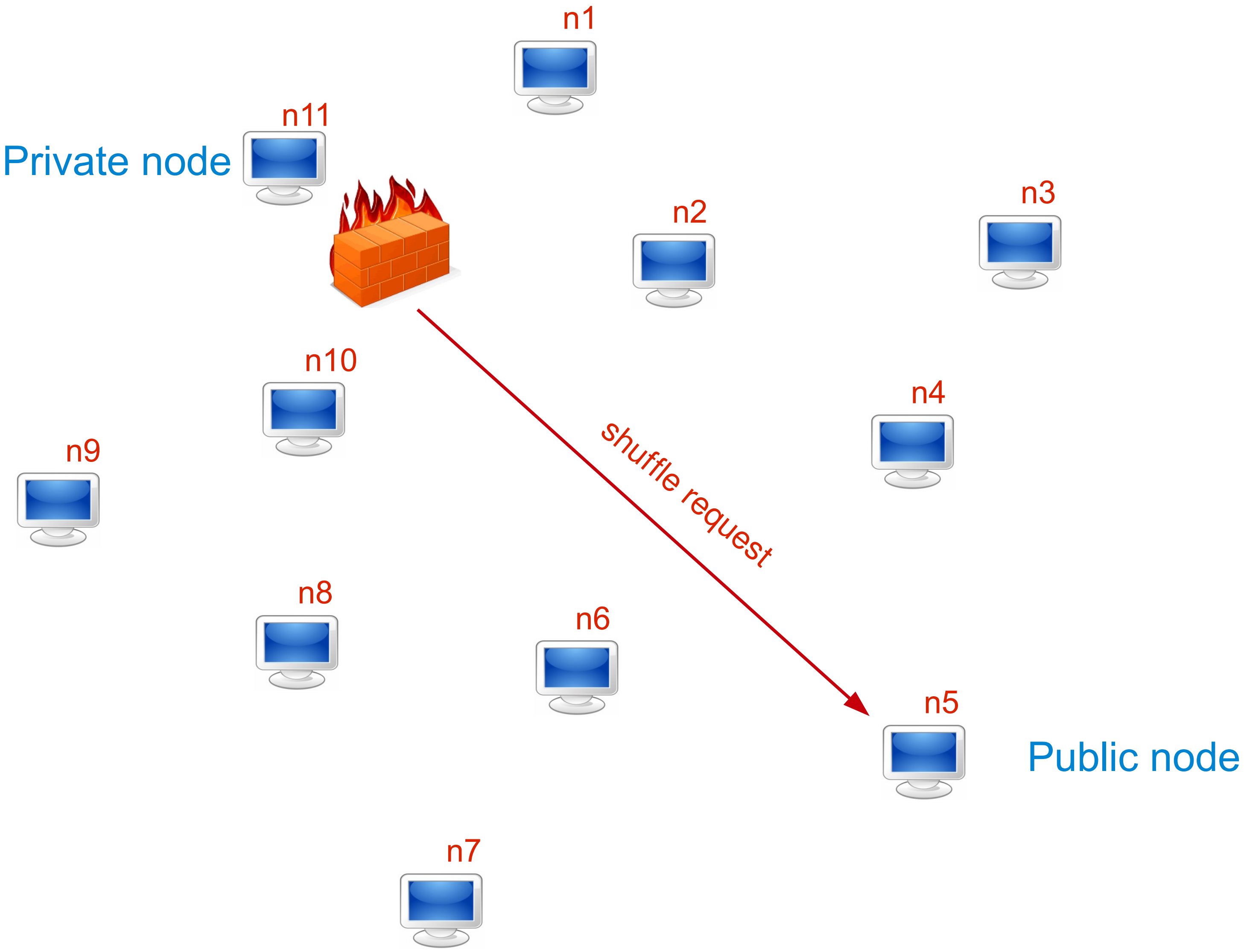
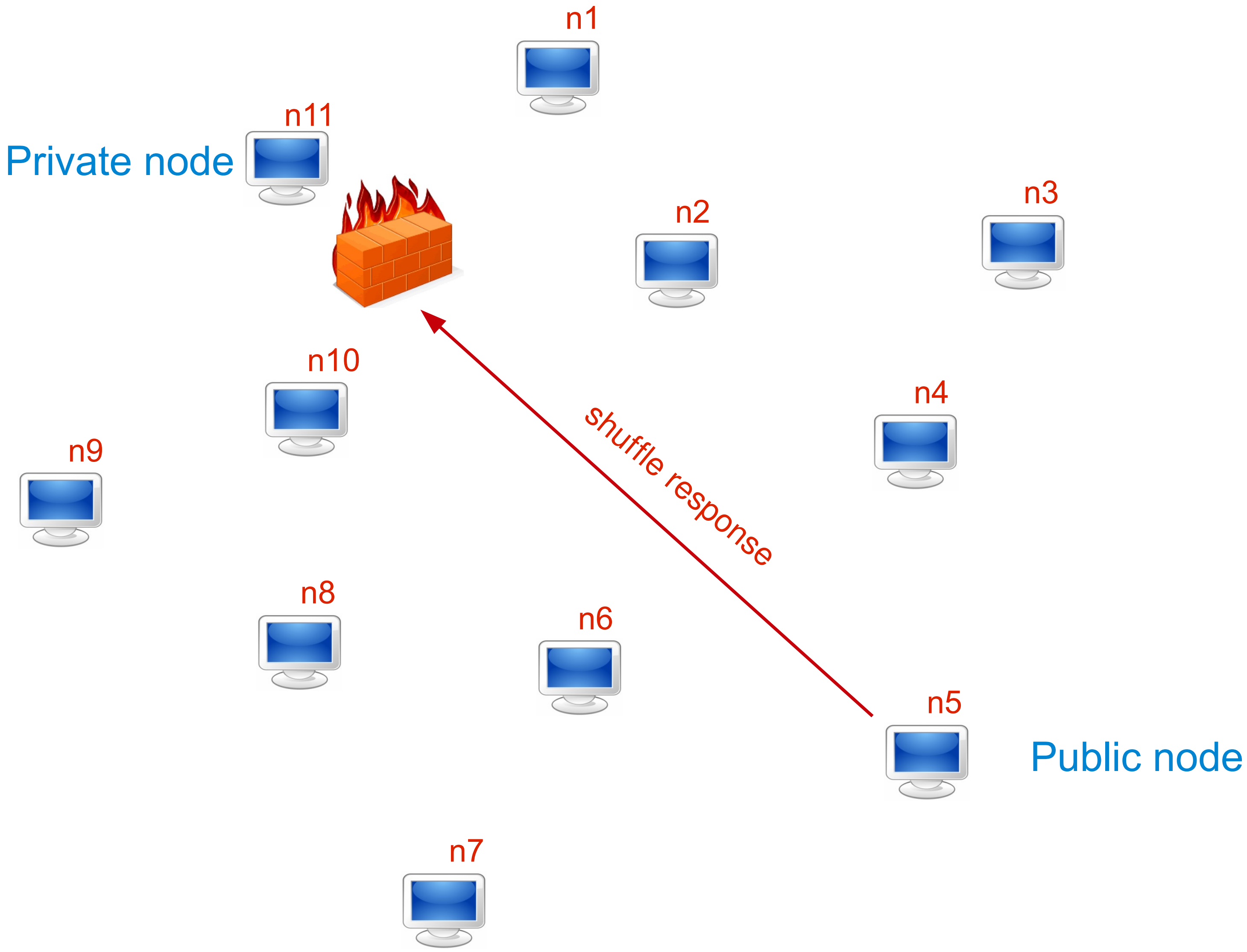


Problem Description

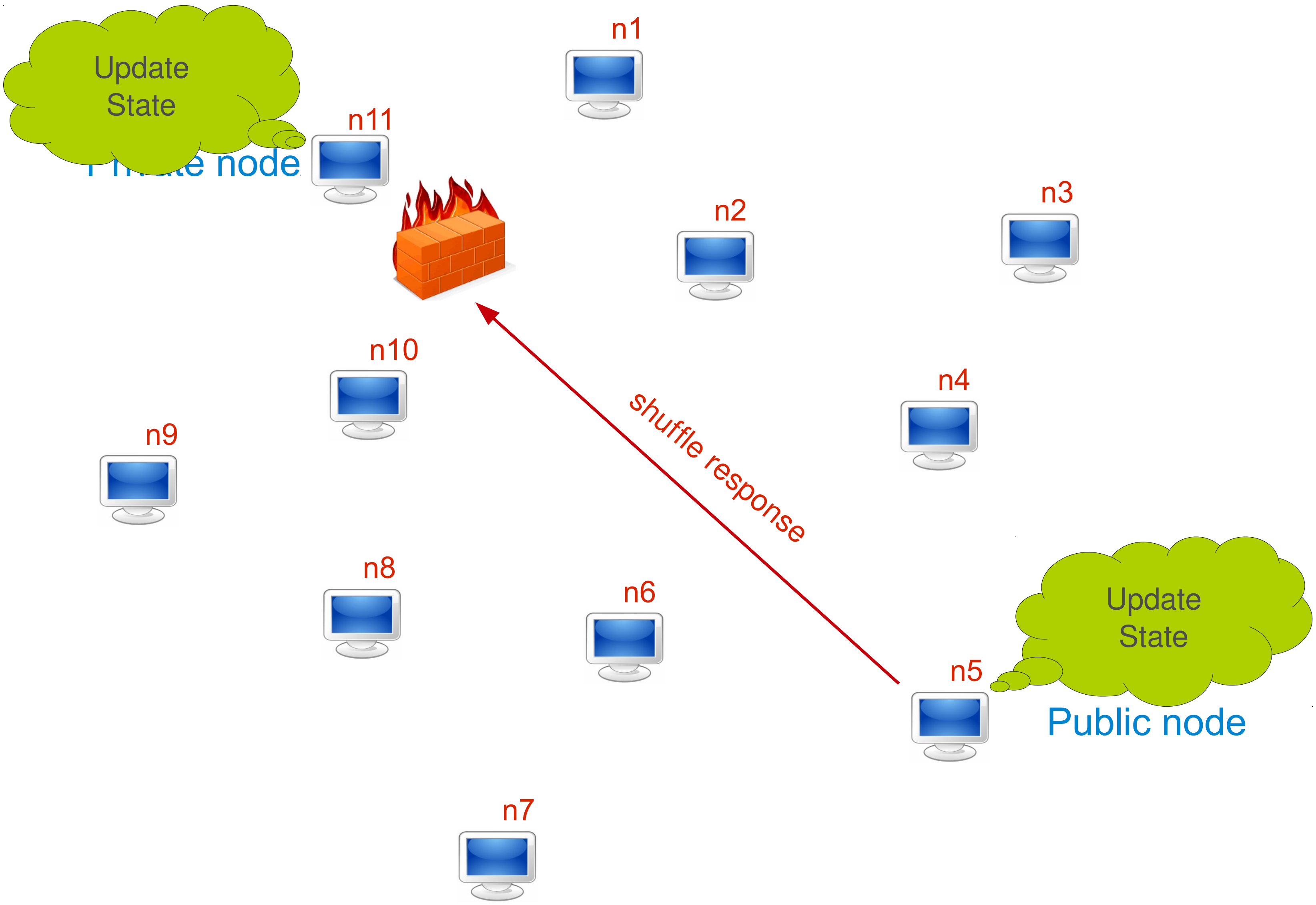
NAT Environments (1/4)



NAT Environments (2/4)



NAT Environments (3/4)



Update State

Private node

n11

n1

n2

n3

n10

n4

shuffle response

n9

Update State

n8

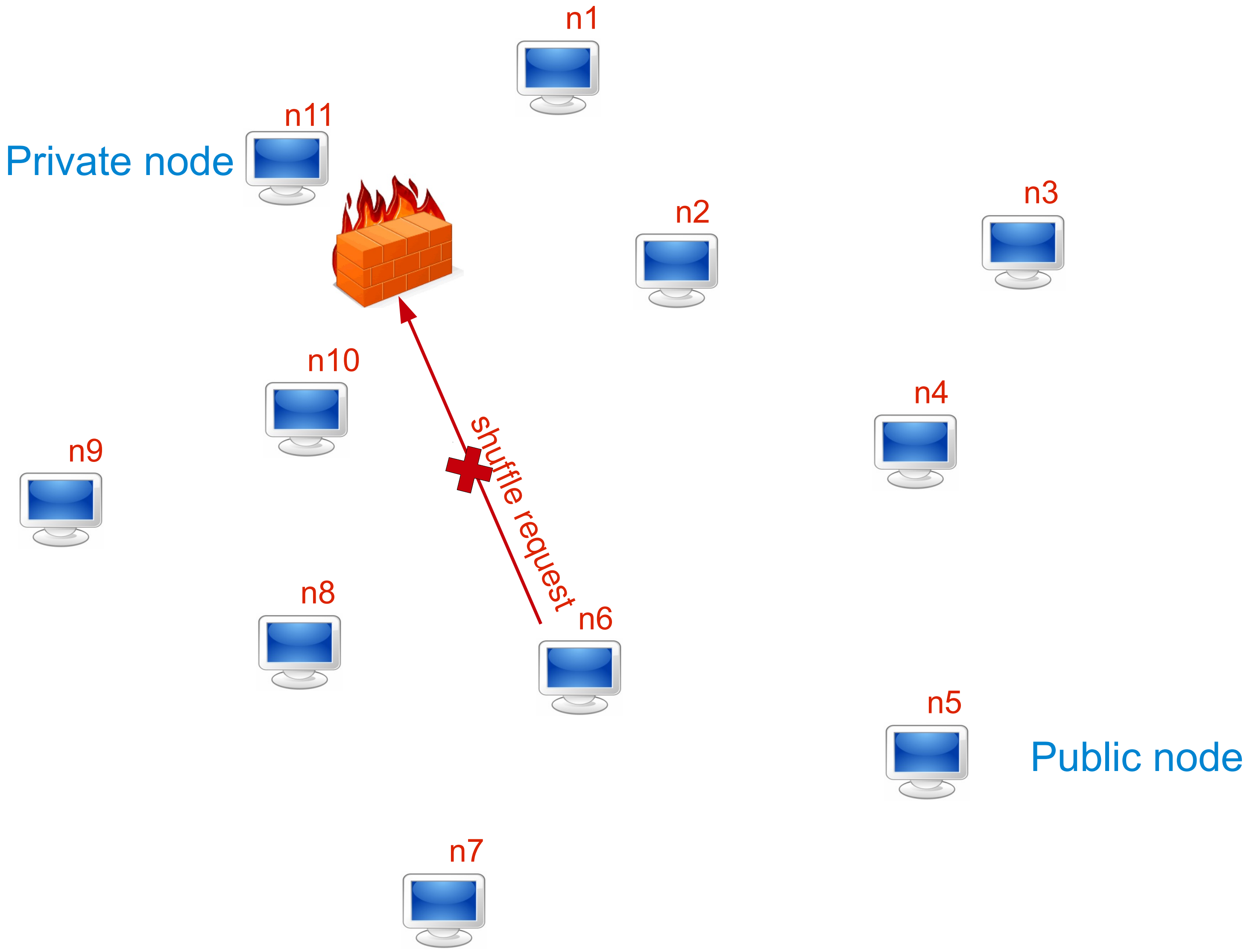
n6

n5

Public node

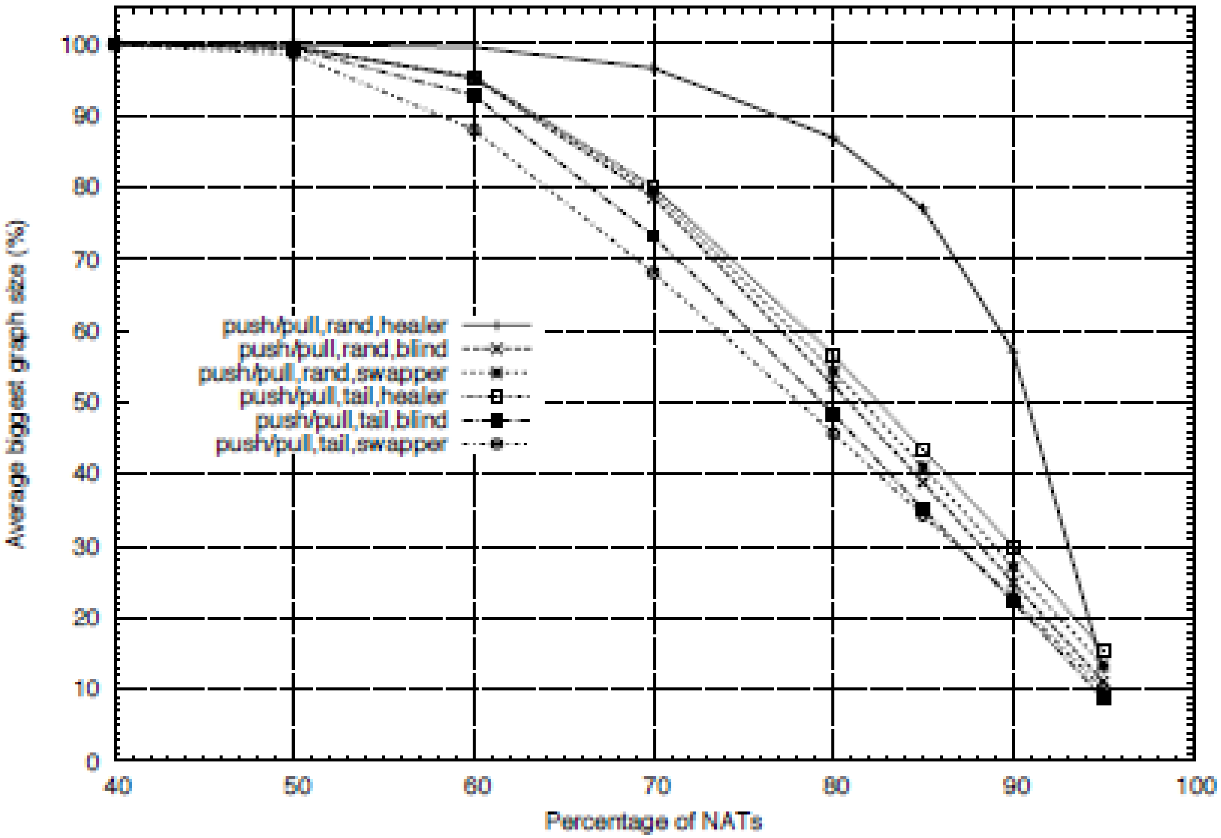
n7

NAT Environments (4/4)



Impact of NATs on PSS' (1/2)

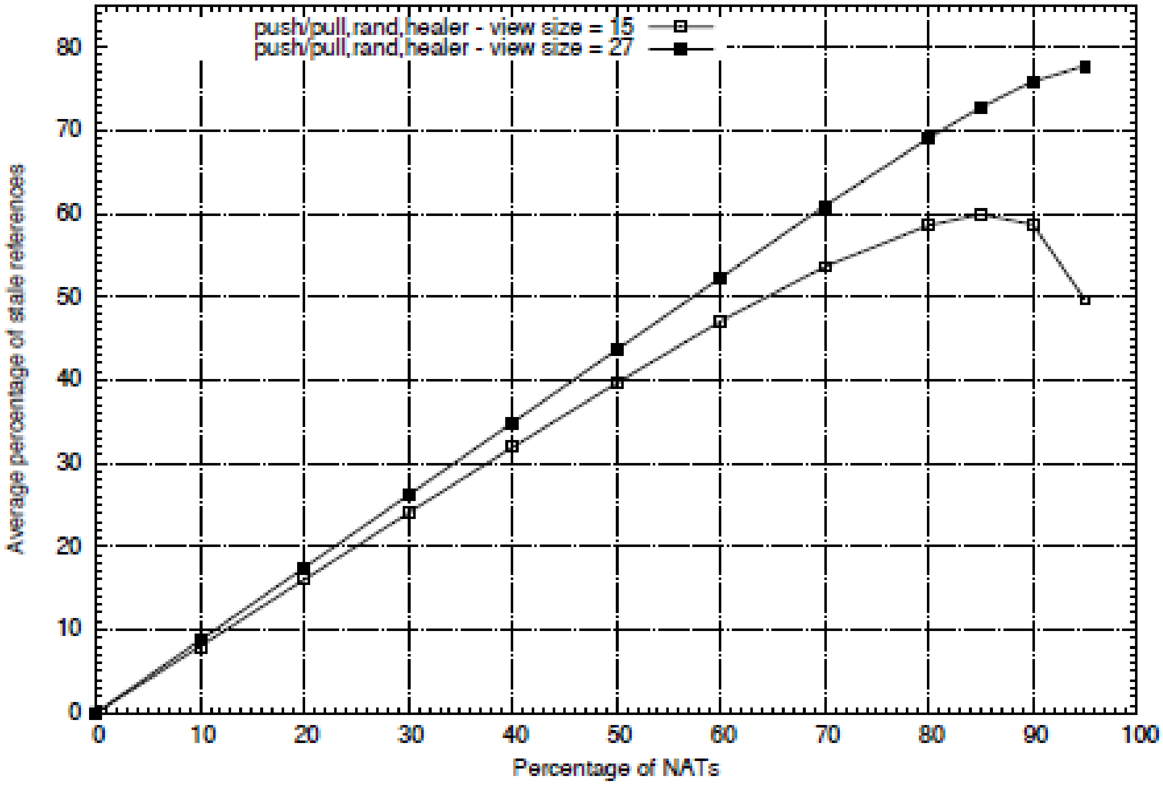
- Size of the biggest cluster for an increasing percentage of NATs.



[A.M.Kermarrec – ICDCS'09]

Impact of NATs on PSS' (2/2)

- Percentage of stale references.

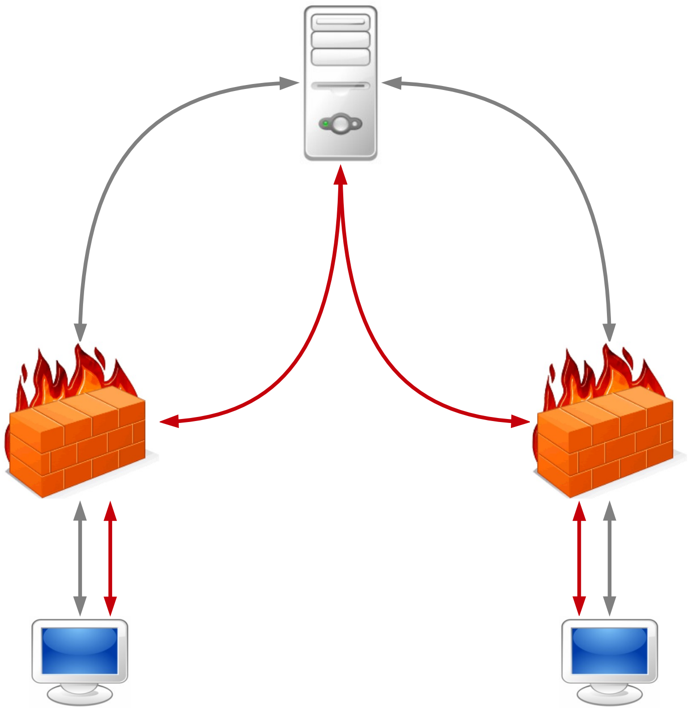


[A.M.Kermarrec – ICDCS'09]

How to Deal With This?

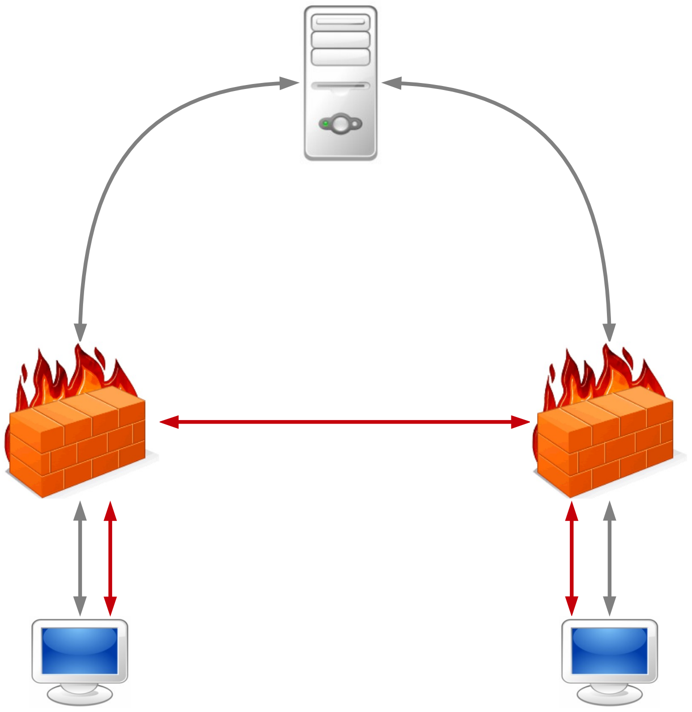
Solutions for Communicating with Private Nodes (1/2)

- Relay communications to the private node using a public relay node.



Solutions for Communicating with Private Nodes (2/2)

- Use a NAT hole-punching algorithm to establish a direct connection to the private node using a public rendezvous node.



Existing NAT-aware PSS

- Existing gossip-based NAT-aware Peer Sampling Services' (PSS) are similar to classic PSS:
  - Single partial view.
  - Periodically exchange partial views with random nodes.

- But, if the selected node is a private node
  - First, the relay node for that private node is discovered.
  - Then a view exchange is done through the relay node.

Problems of the Existing Solutions

- Nodes have to discover relay nodes.
- Private nodes have to maintain open mapping in their NAT.
- Relaying nodes have to maintain routing tables.

Croupier

The Croupier Protocol

- A NAT-aware gossip-based PSS without the use of relaying or hole-punching.
- Public nodes are croupiers.
- Each node keeps two views:
  - Public view
  - Private view

Croupier in a Nutshell

- Continuously update the nodes' public/private views.
- Estimate the ratio of the public nodes in the system, and take a uniform sample based on the estimated ratio.

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- Sender and receiver both update their public/private views:
  - By first merging the views, and then if the view size exceeds its upper-bound, replacing the sent nodes with the received nodes.

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Providing Uniform Sample at Nodes

- Each node estimates the ratio of the public nodes in the network: $E_i(\omega)$

- They sample the nodes from the public/private views proportional to the estimated ratio.
  - For example, if $E_i(\omega)$= 20%, and the public/private view sizes are 10, then a node samples the nodes by taking 2 nodes from the public view and 8 nodes from the private view.

Ratio Estimation at Public Nodes

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    - Public nodes: c_u
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Not accurate enough

Ratio Estimation at Public Nodes

- The public nodes piggyback their estimated ratio E_i in each shuffle response.

- Any node i keeps track of the γ recent received estimation from public nodes in a local list: M_i

- Then, the each public node measures the ratio of the public nodes in the system:

$$E_i\left(\omega\right) = \frac{\sum\limits_{n \in M_i} E_n + E_i}{|M_i| + 1}$$

Ratio Estimation at Private Nodes

- The private nodes do not receive any shuffle request. So, they can not estimate E_i for the last α rounds.

- But, they receive the public nodes estimation in shuffle responses, and keep the γ recent received estimation at M_i.

- So, they measure the ratio of the public nodes as follows:

$$E_i\left(\omega\right) = \frac{\sum\limits_{n \in M_i} E_n}{\left|M_i\right|}$$

Experiments

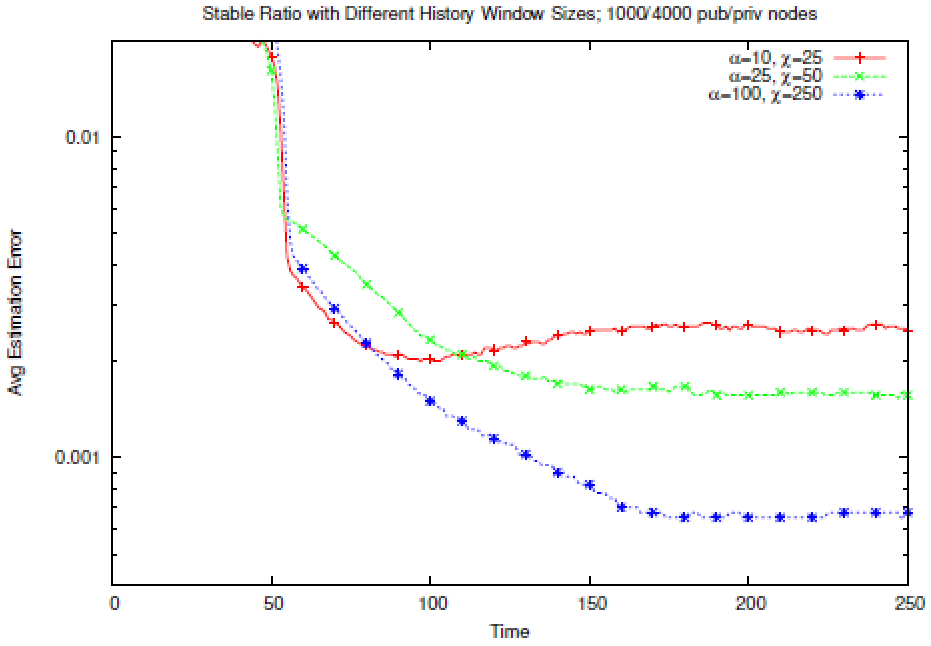
Experiment Setup

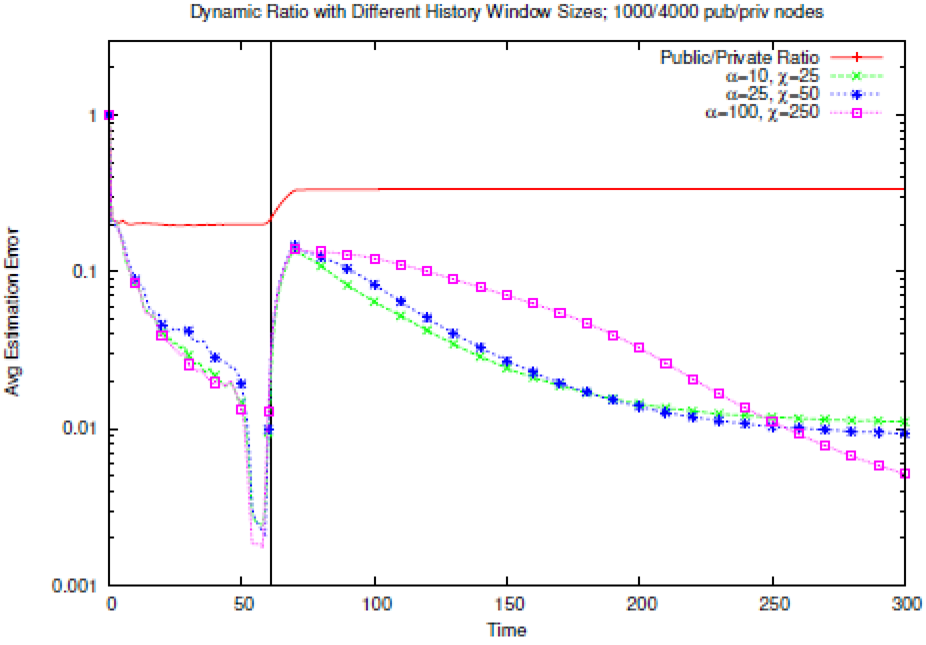
- We used Kompics as a simulator platform.
- The public/private views sizes are 10, and the shuffling period is one second.
- 5000 nodes, 80% of nodes are private and 20% are public.
- Compared with Gozar and Nylon.
    - Gozar uses a single rendezvous node for relaying.
    - Nylon uses a chain of nodes to enable direct communication between nodes by the use of hole punching.
- Cyclon is used as a baseline.

Metrics

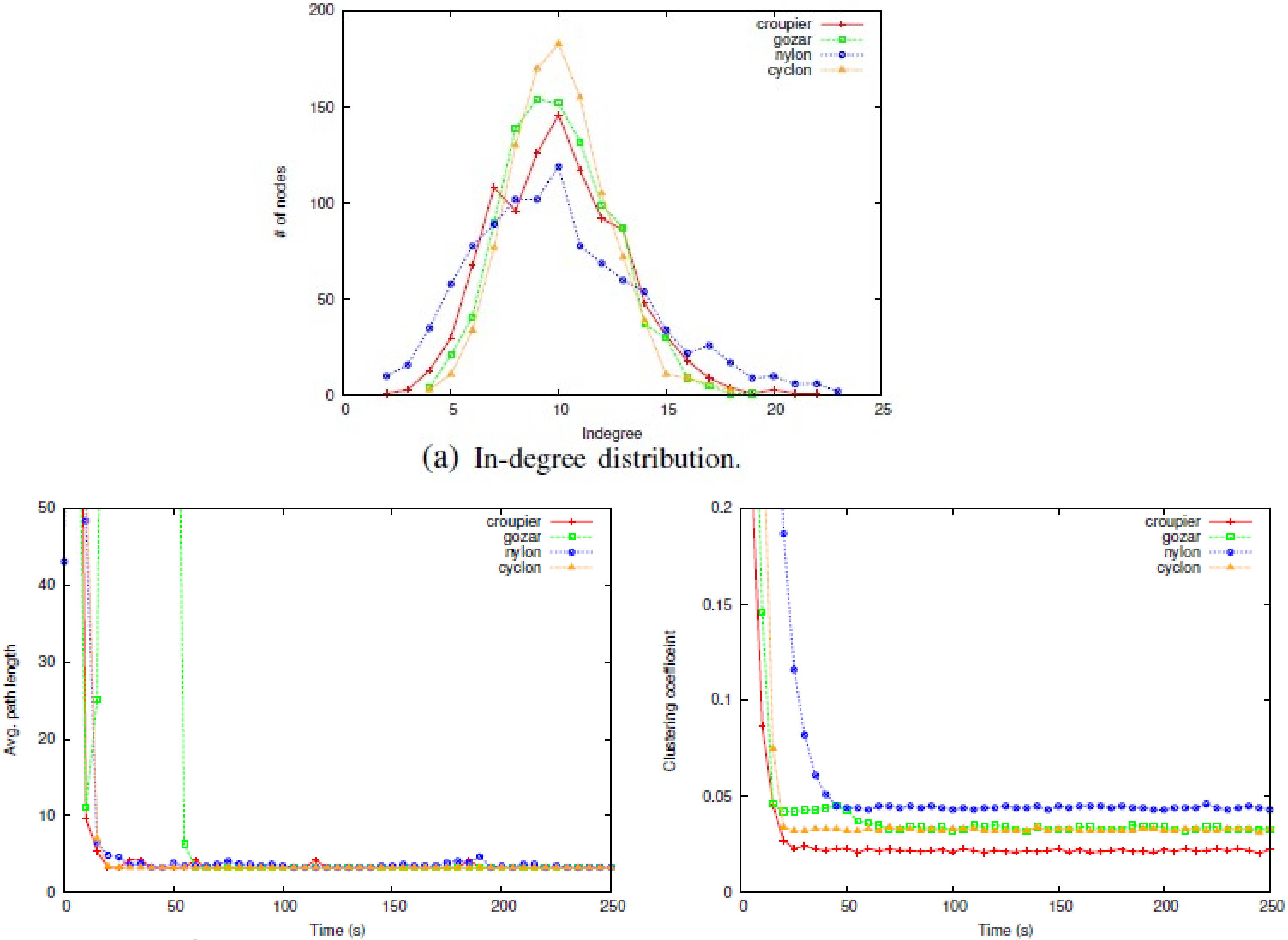
- Correctness of the estimation in static and dynamic network.
- Randomness properties.
- Protocol overhead.
- Fairness and connectivity in catastrophic failure.

Ratio Estimation





Randomness

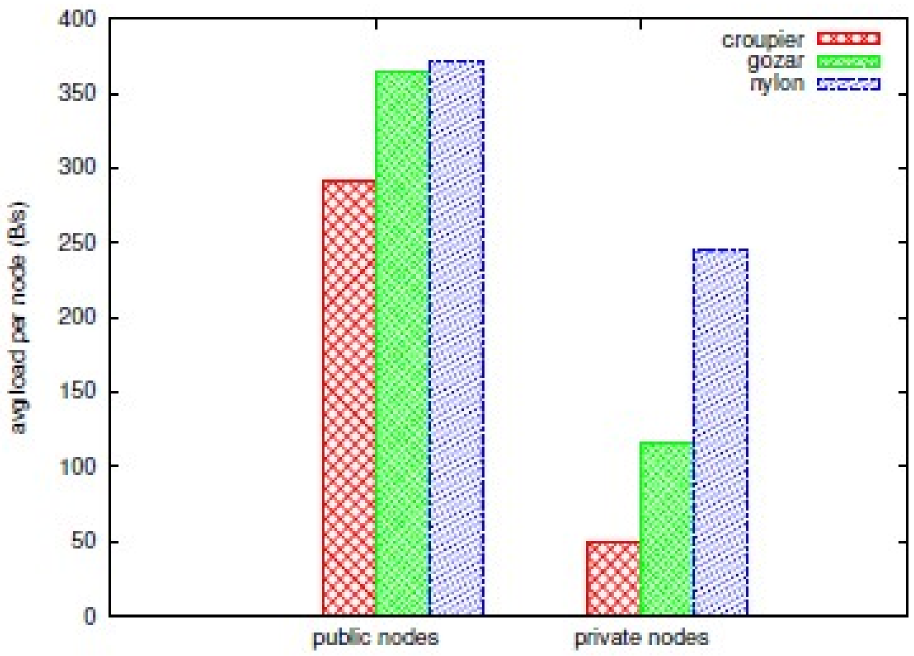


(a) In-degree distribution.

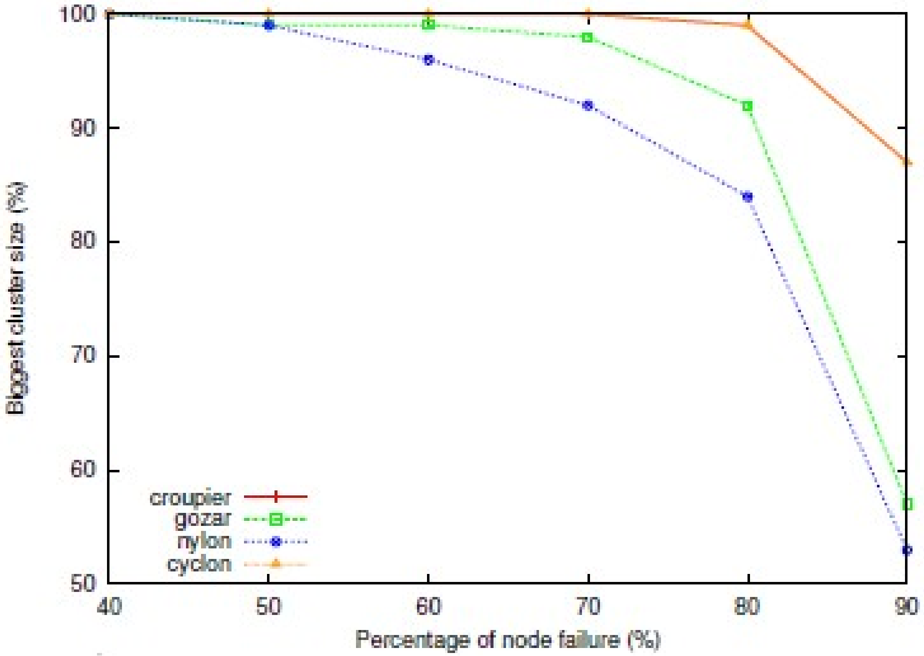
(b) Avg. path length.

(c) Clustering co-efficient.

Protocol Overhead



Connectivity in Failure



Conclusions

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- Croupier is a NAT-friendly gossip-based peer sampling without the use of relaying.
- Shuffle requests are sent only to the public nodes, but all the nodes receive both shuffle responses.
- Each node keeps two views for public nodes and private nodes.
- The nodes estimate the ratio of public nodes, and use it to take a uniform sample of all the nodes in the system.

Questions?