Scalable Routing
for
Embedded Networks
and
Mobile P2P Applications

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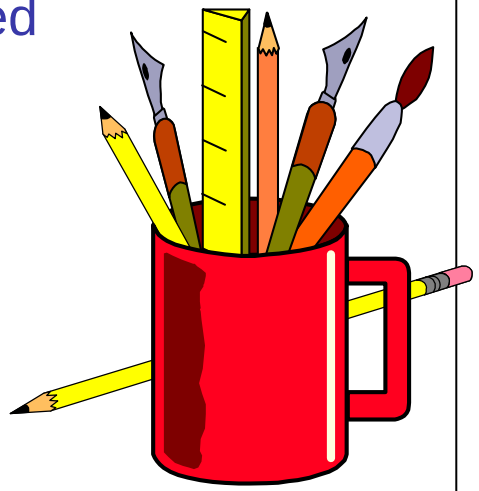
Motivation: Moore‘s Law

Swiss Army Knife

1. Moore‘s law makes electronic devices more powerful.
2. Software updates provide the devices with ever increasing capabilities.

Toolbox

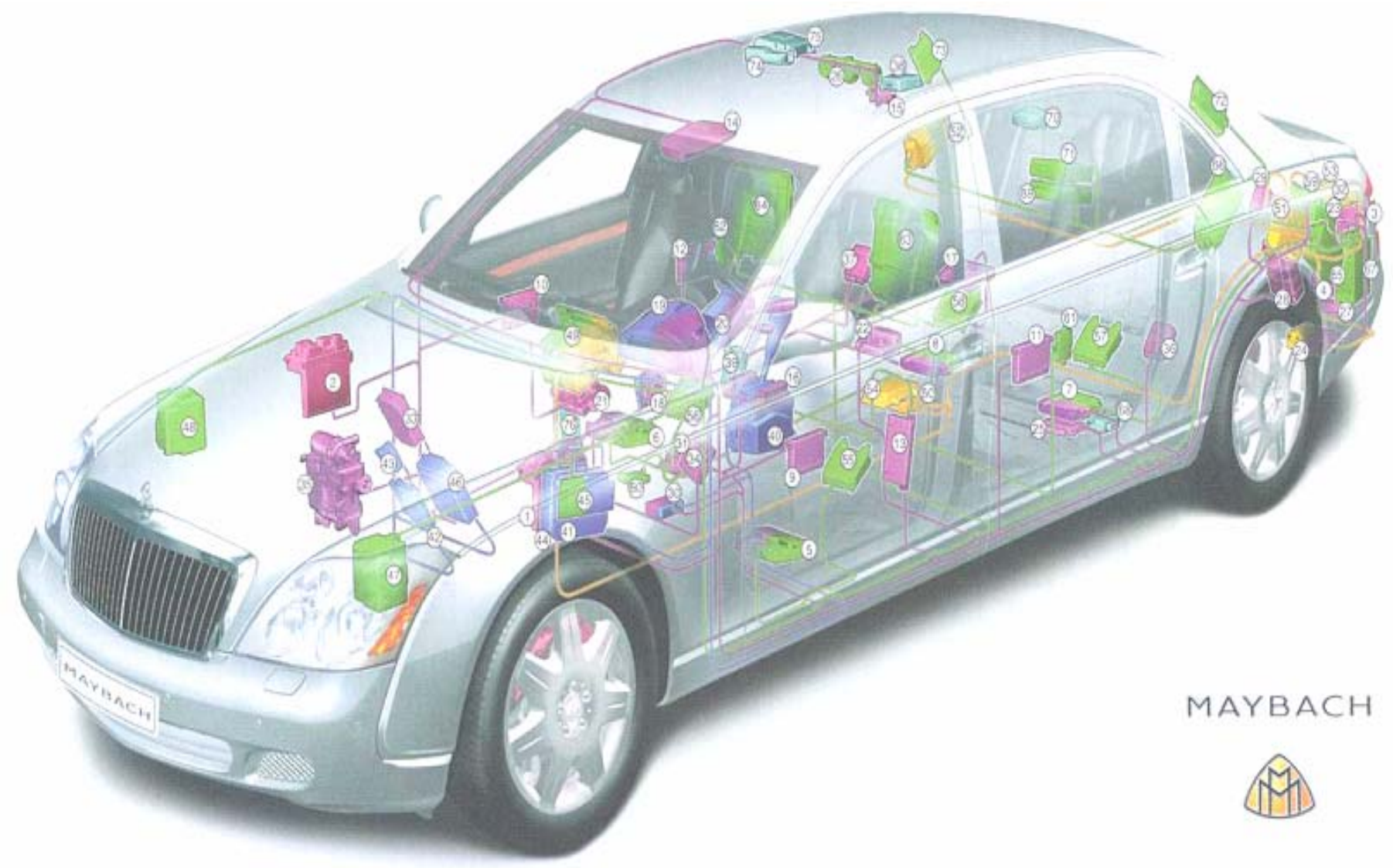
1. Moore‘s law makes computation and communication devices smaller and cheaper.
2. Physical tools can be enhanced with electronics.



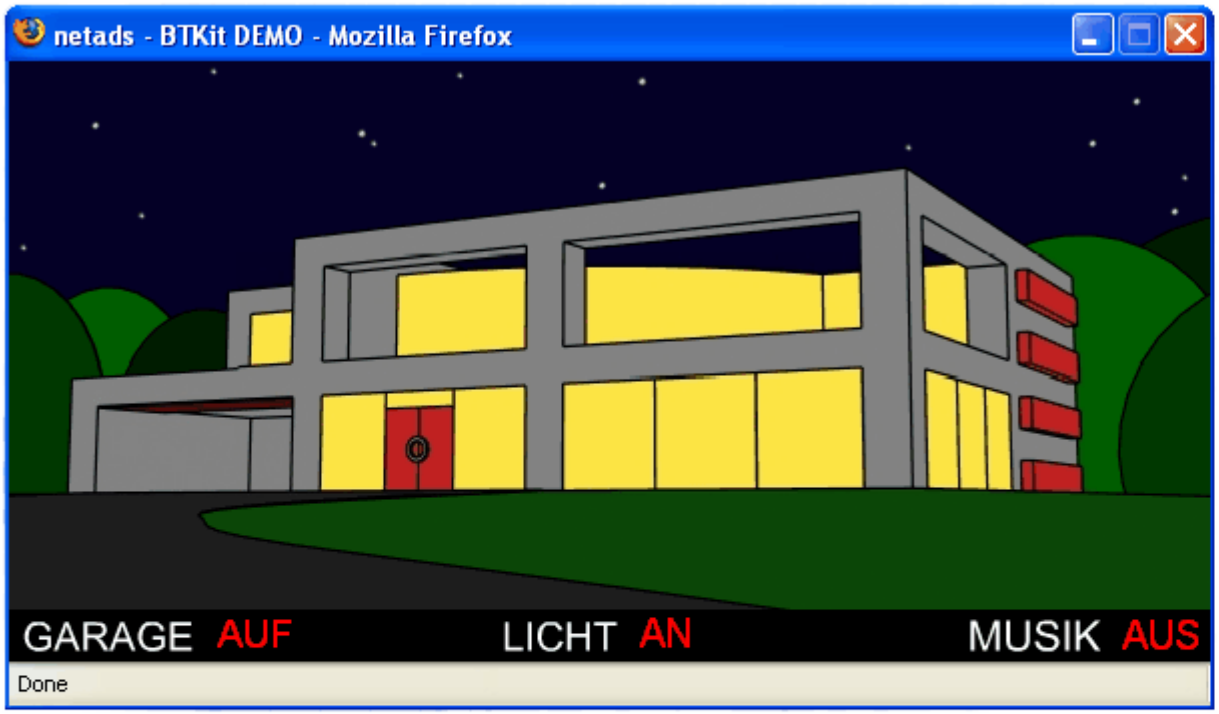
Our field of research:

Algorithms and protocols for distributed systems in the toolbox scenario.

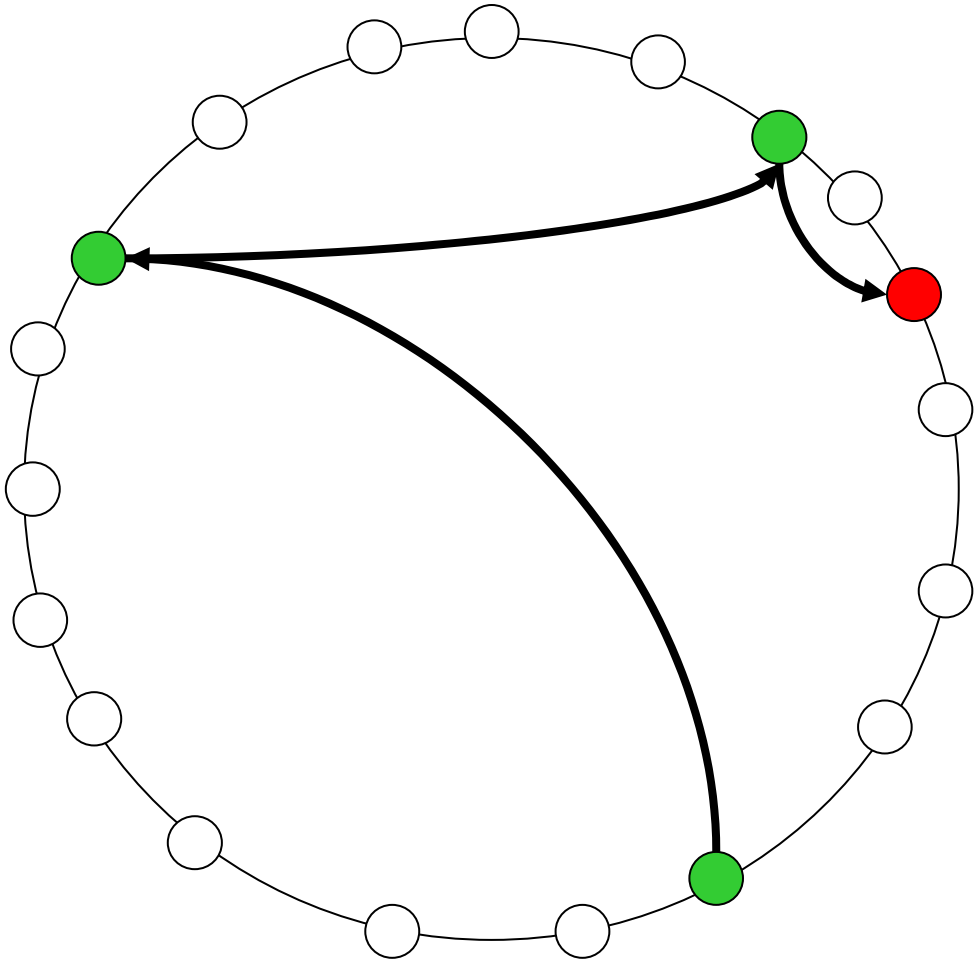
Cars already have plenty of electronics …

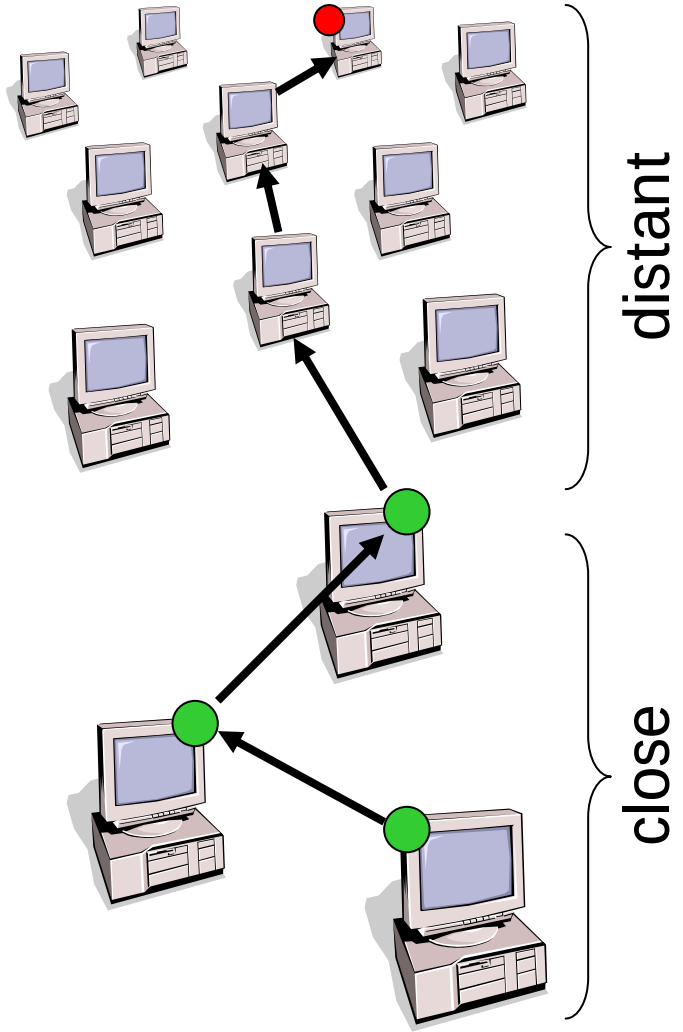


… are everyday environments next?



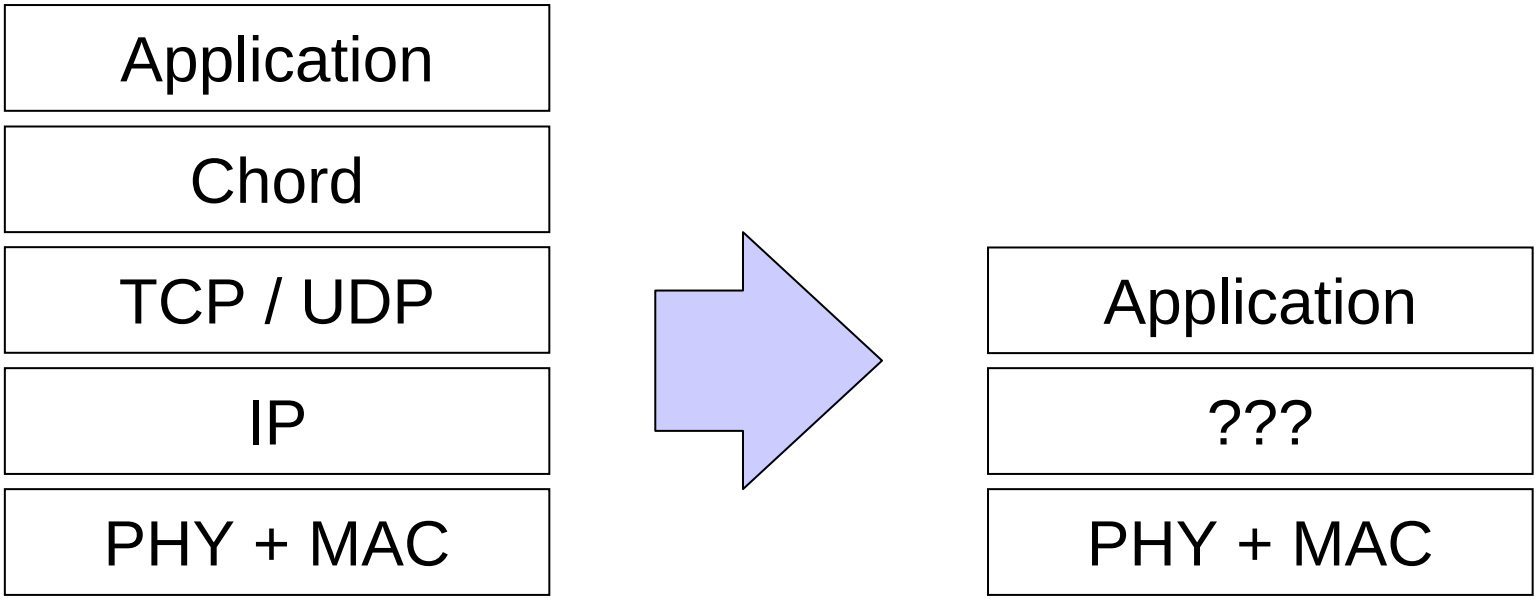
Proximity Awareness with Chord





Can we Push Chord into the Underlay?

Does this Chord idea help
us with our sensor actuator vision
of thousands of houses with
hundreds of nodes each?

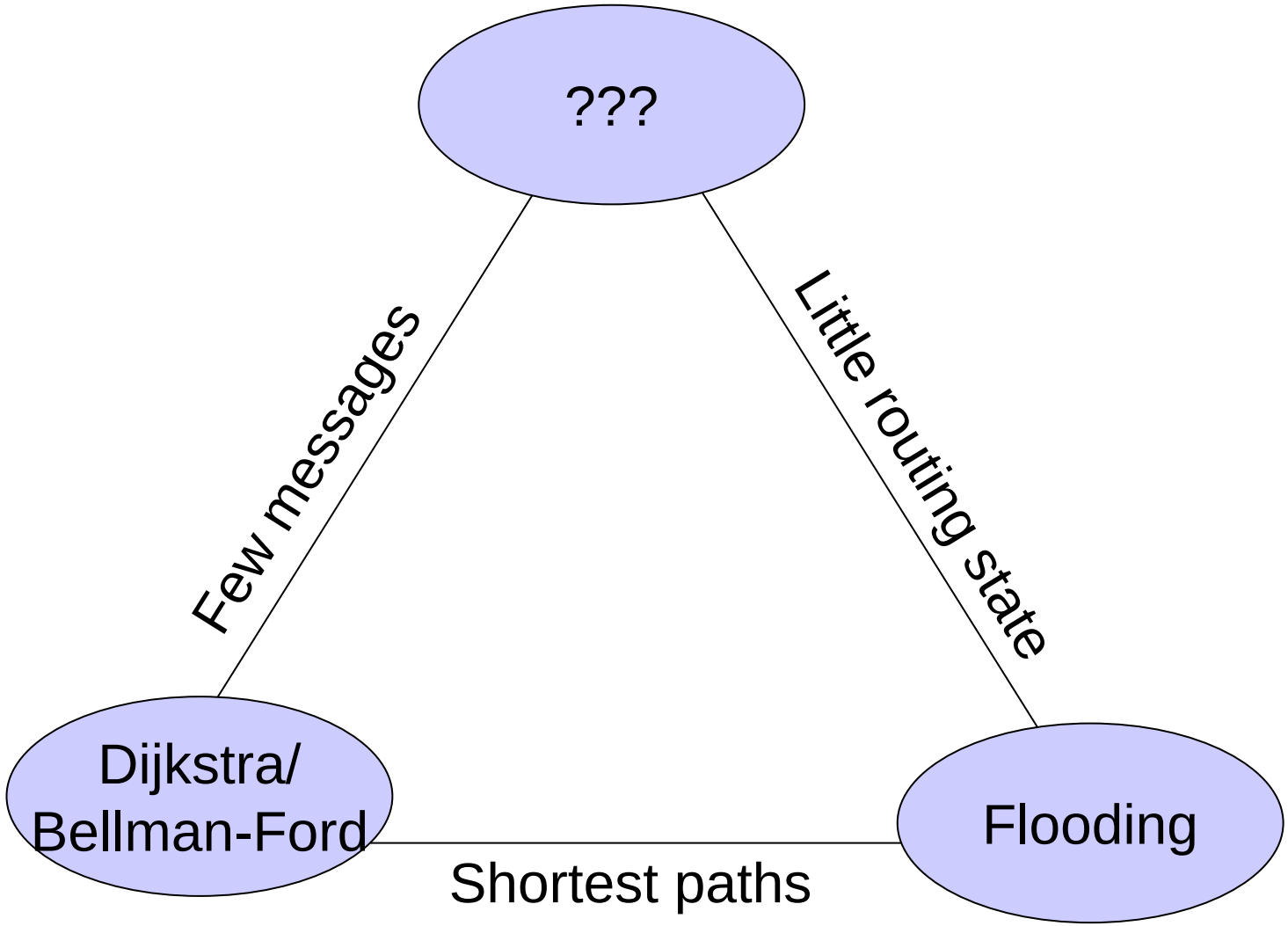


Routing – An Overview

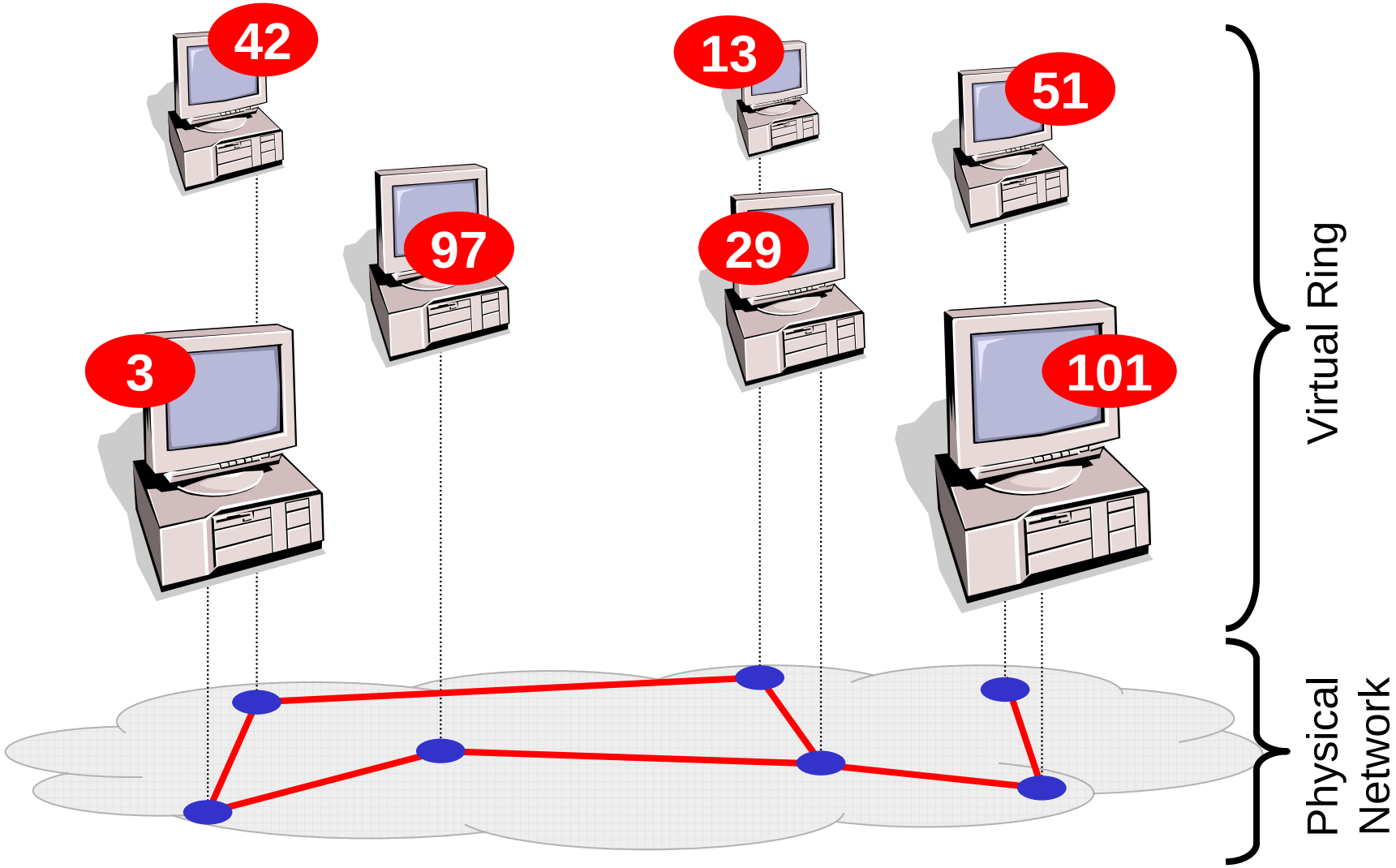
Shortest path, but large routing tables unless network is specially structured!

Shortest paths, but many messages unless network is specially structured!

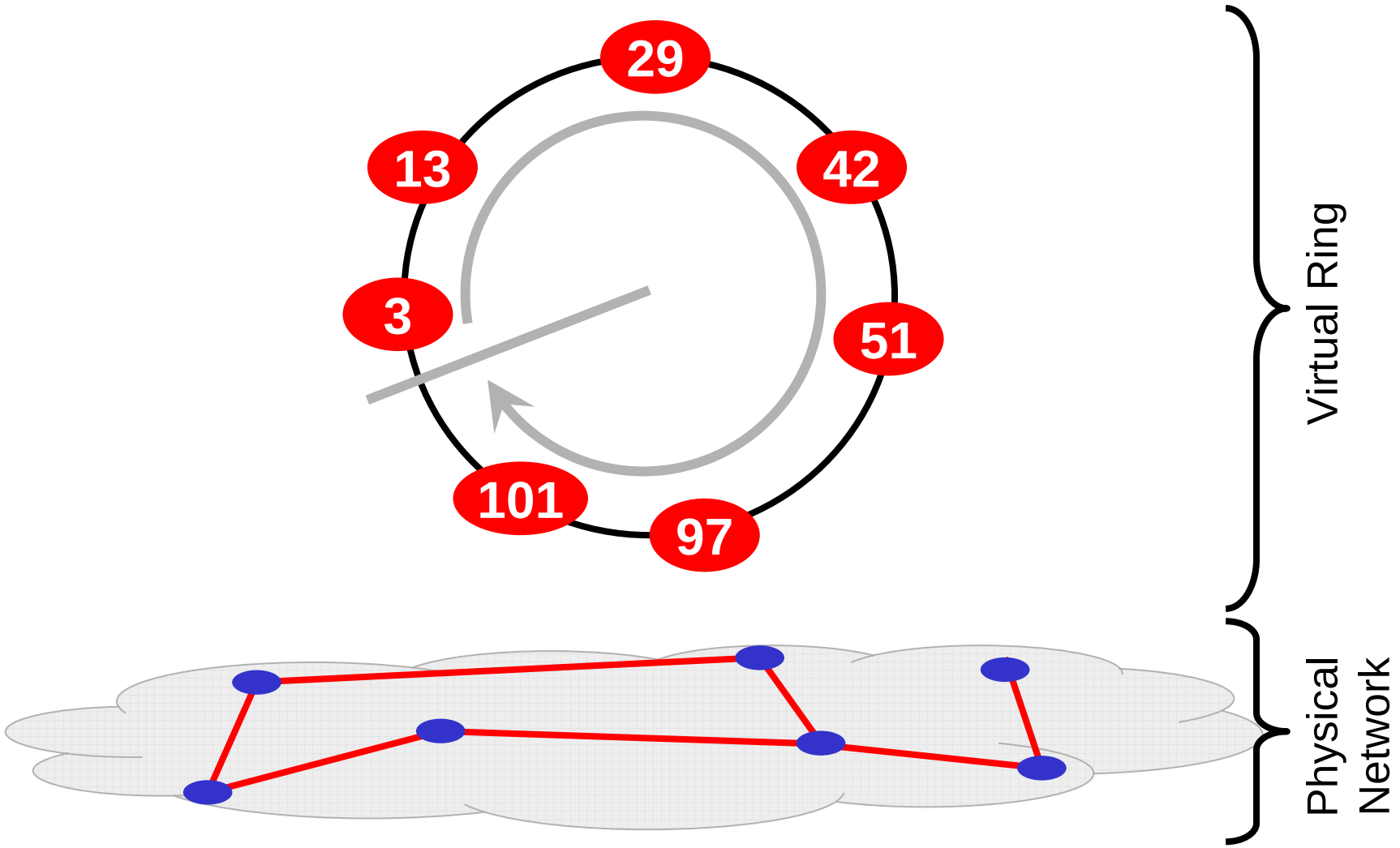
Routing – An Overview



Use Chord's Virtual Ring



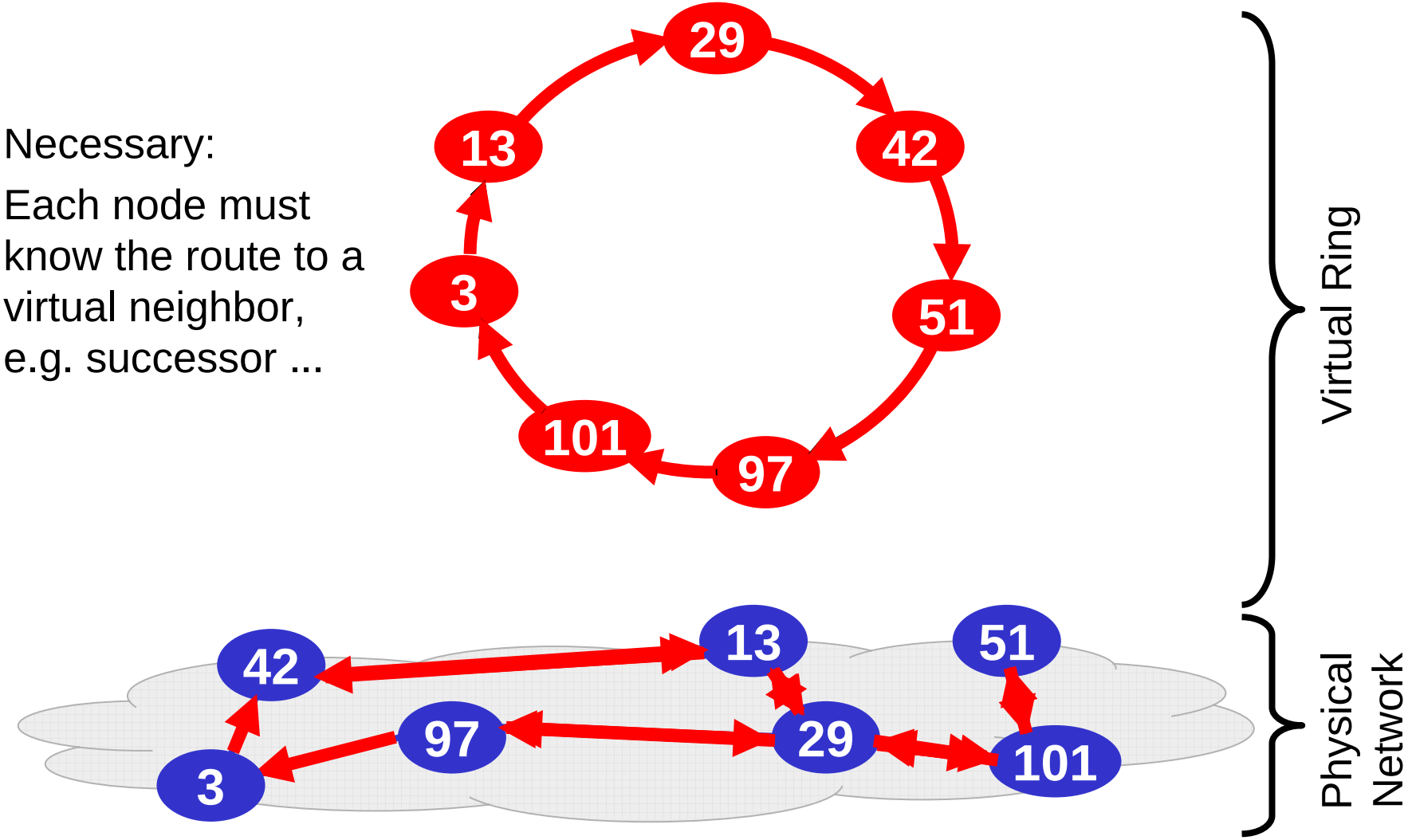
Use Chord's Virtual Ring



Source Routes Form the Virtual Ring

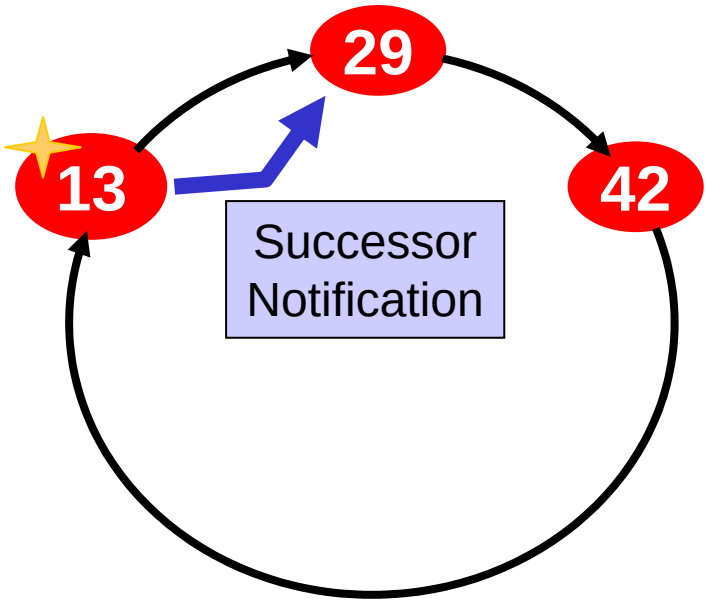
Necessary:

Each node must know the route to a virtual neighbor, e.g. successor ...

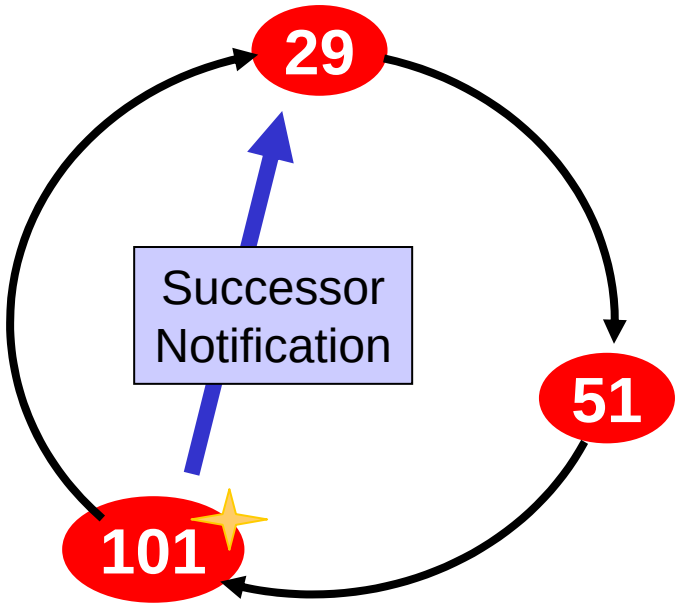


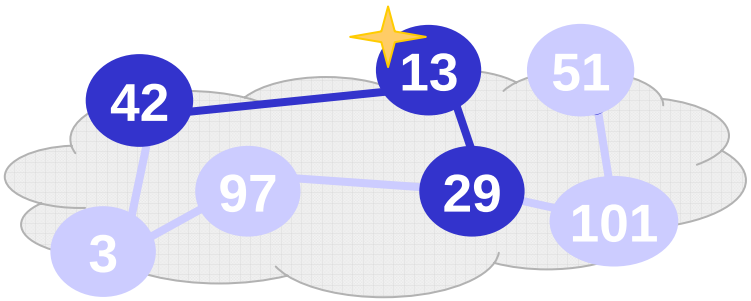
Iterative Successor Search (1)

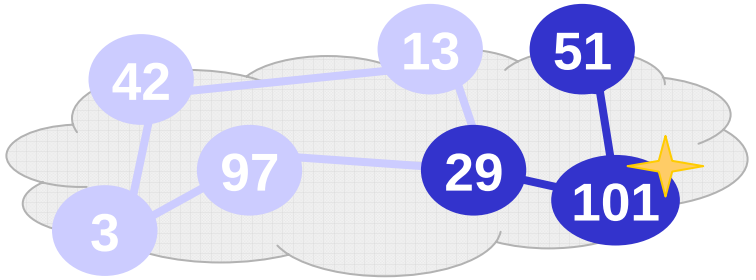
Viewed from node 13:



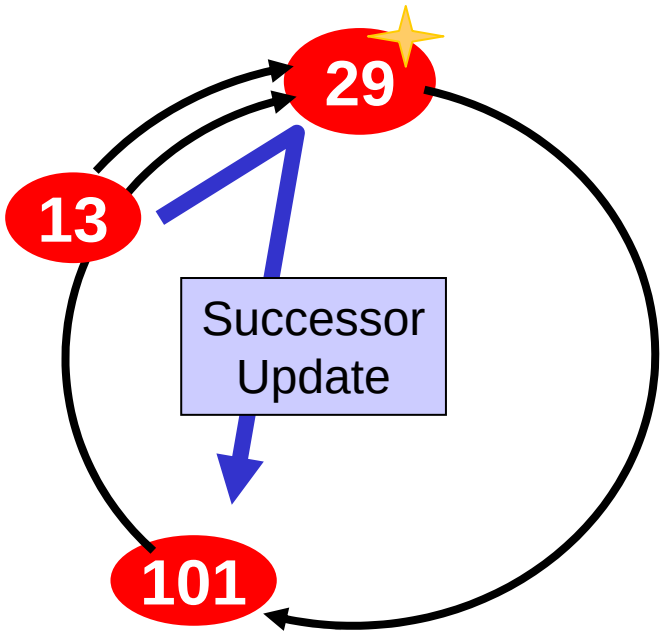
Viewed from node 101:

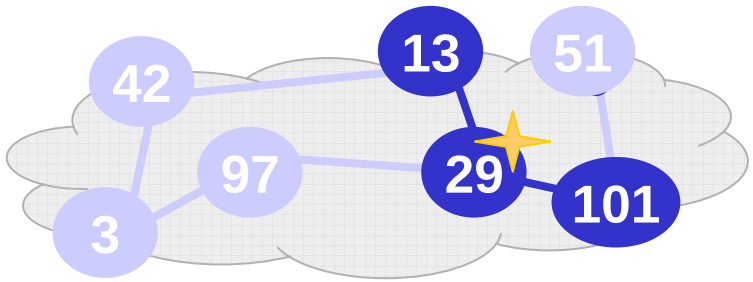






Iterative Successor Search(2)





Node 29 can resolve the inconsistency

Notifications:

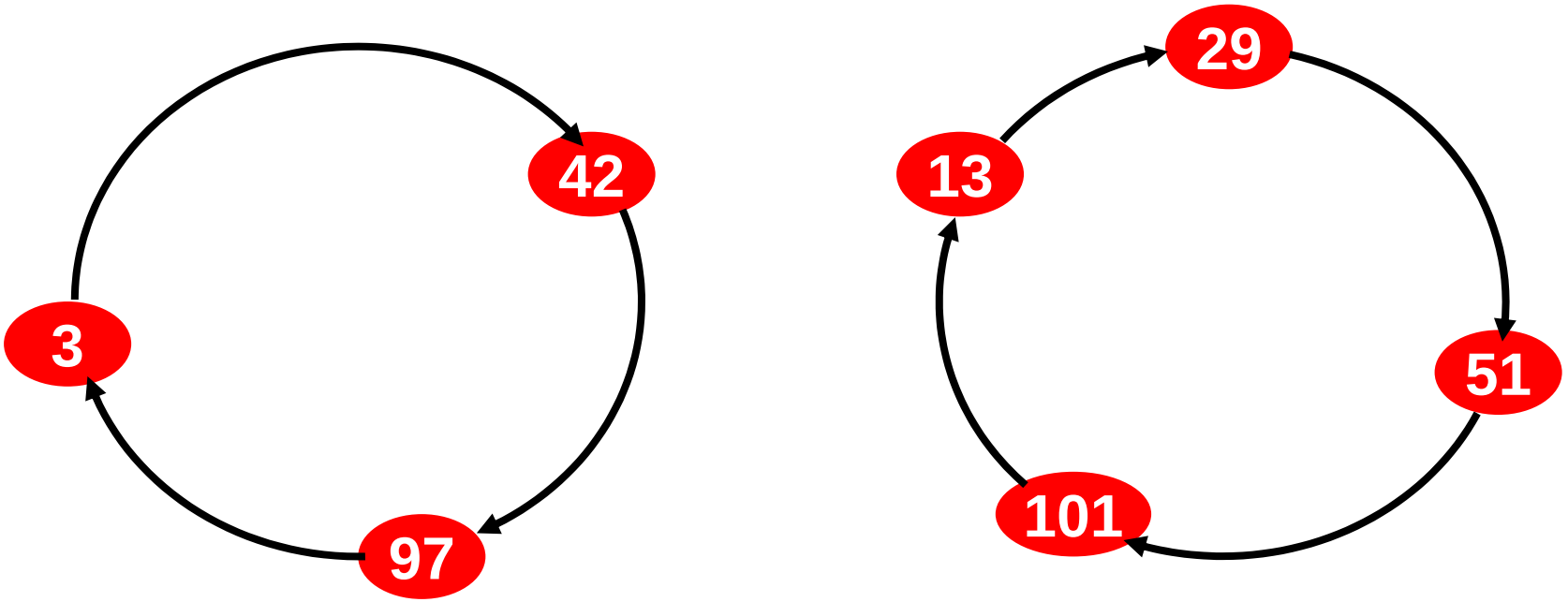
13	29	Notify
101	29	Notify

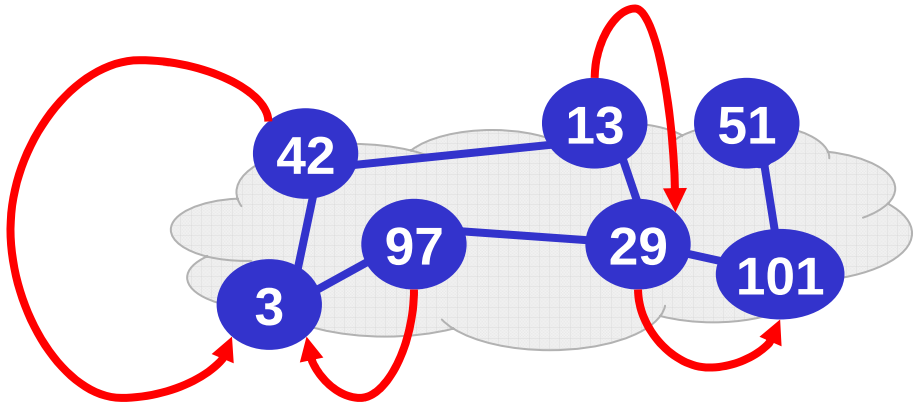
Updates:

13	29

U	101	29	

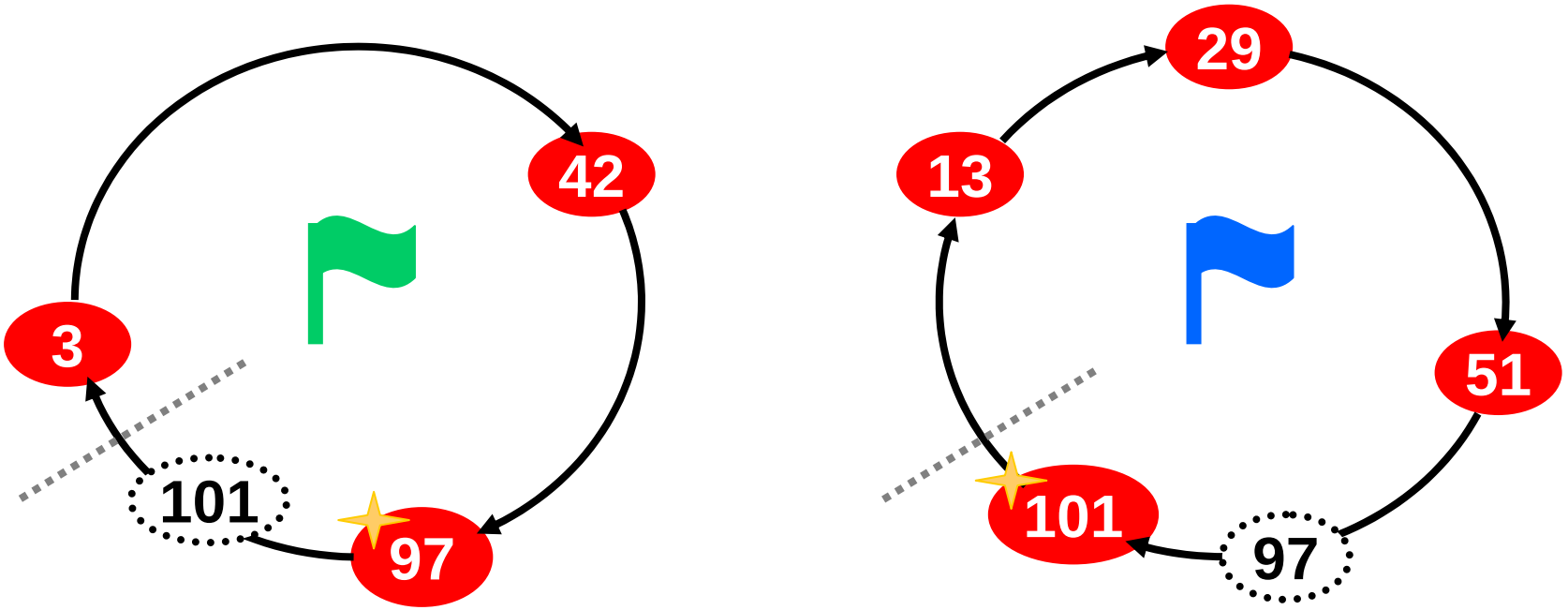
Consistency of the Successor Search (1)

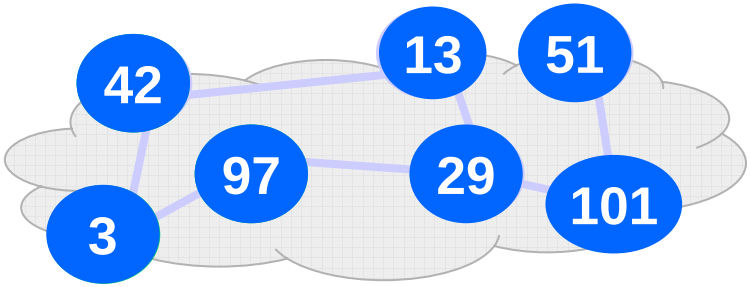




With low probability multiple virtual rings form.

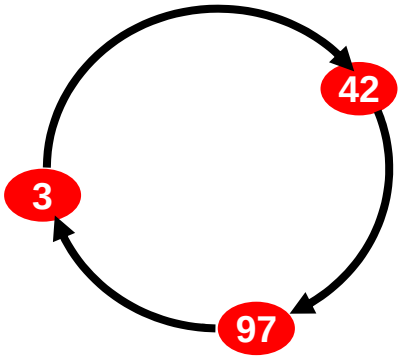
Consistency of the Successor Search (2)

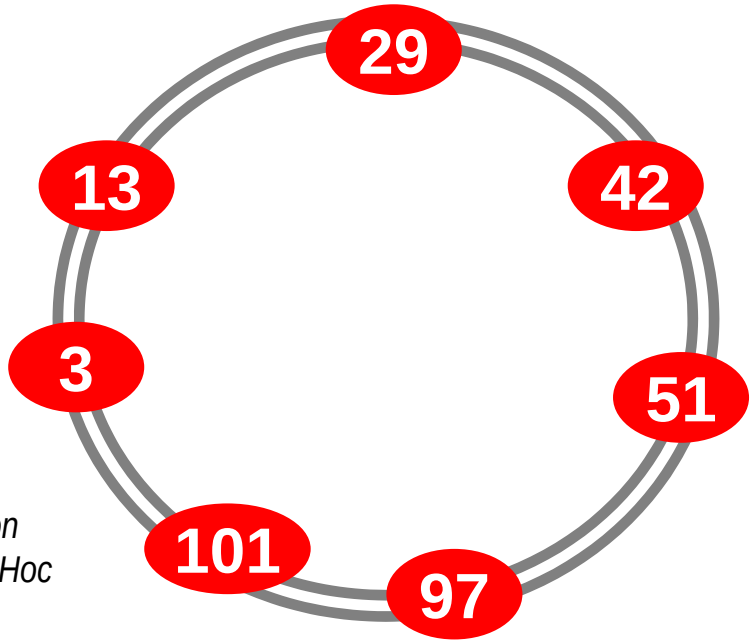


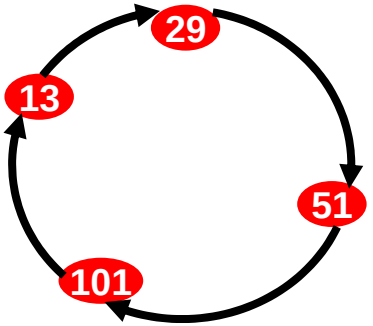


If very few nodes flood the network, the inconsistencies are resolved.

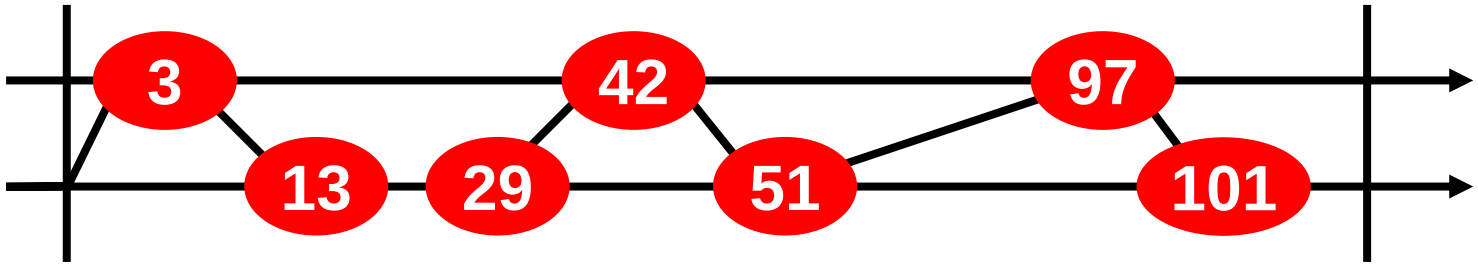
Consistency of the Successor Search (3)







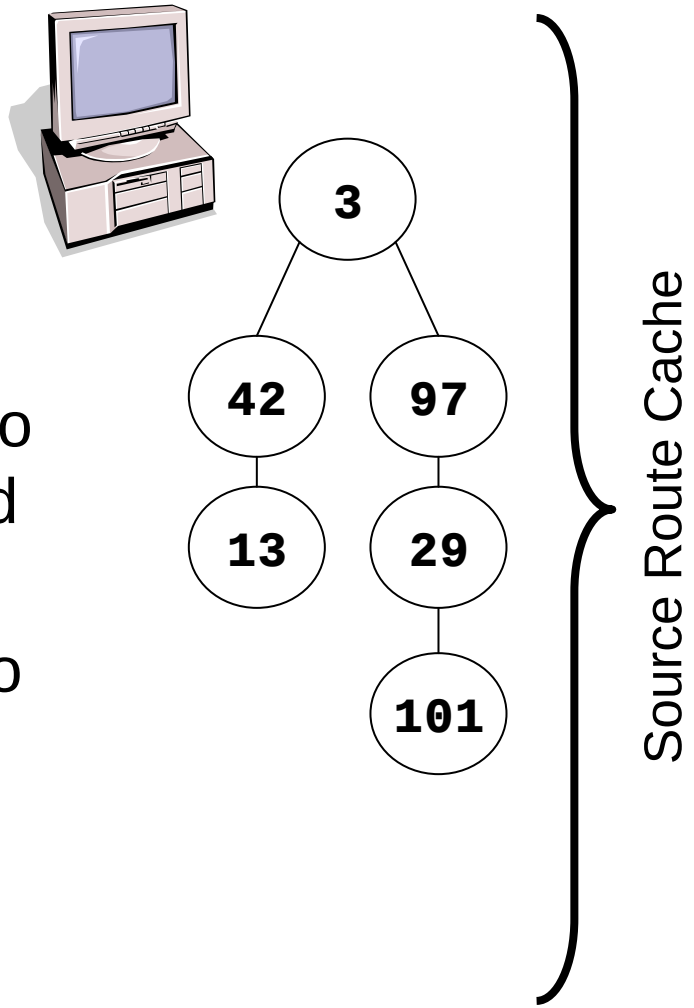
Cramer, Fuhrmann. ISPRP: A Message-Efficient Protocol for Initializing Structured P2P Networks. Proc. IEEE Int. Workshop on Strategies for Energy Efficiency in Ad Hoc and Sensor Networks, 2005.



Source Route Cache (1)

Nodes use static memory:

- Each node stores its direct physical neighbors.
- Each node stores a source route to its successor (cf. Chord).
- Each node stores a source route to its predecessor (to be able to send updates).
- All remaining memory (assigned to routing) is used to cache source routes in a LRU manner.



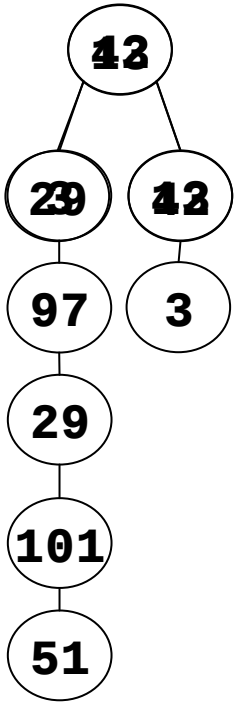
Fuhrmann, Scalable Routing in Random Networks, Networking 2005.

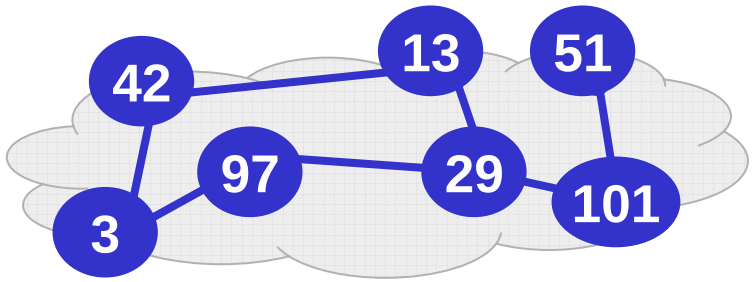
Source Route Cache (2)

- Upon a ‚cache miss' the message is forwarded to the node that
  - Lies before the target (in direction of the ring),
  - is physically closest to the forwarding node, and that
  - virtually closest to the target.

Example: **13 → 51**

13	42	3	97	29	101	51





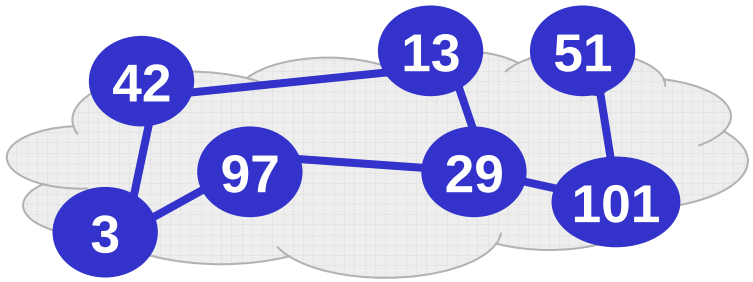
Source Route Cache (3)

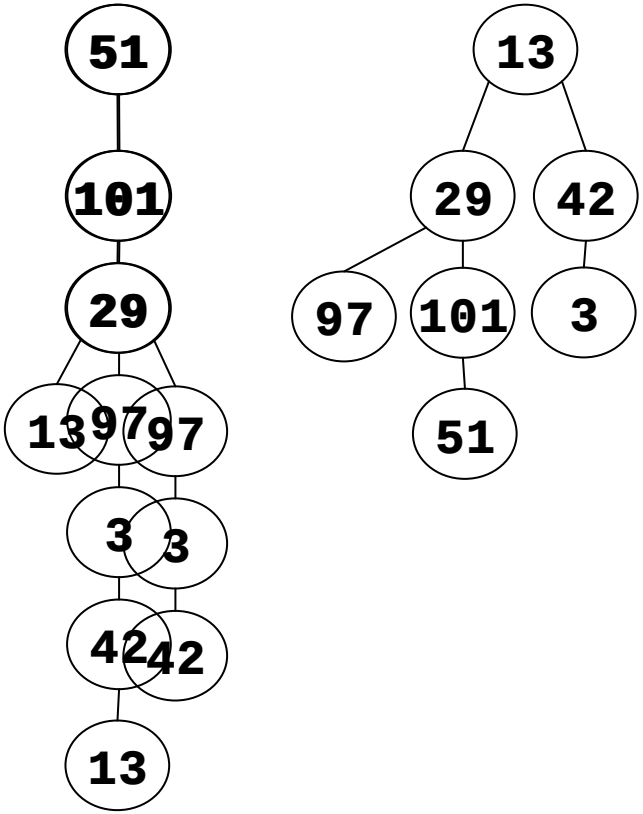
The cache accumulates short routes:

13	42	3	97	29	101	51

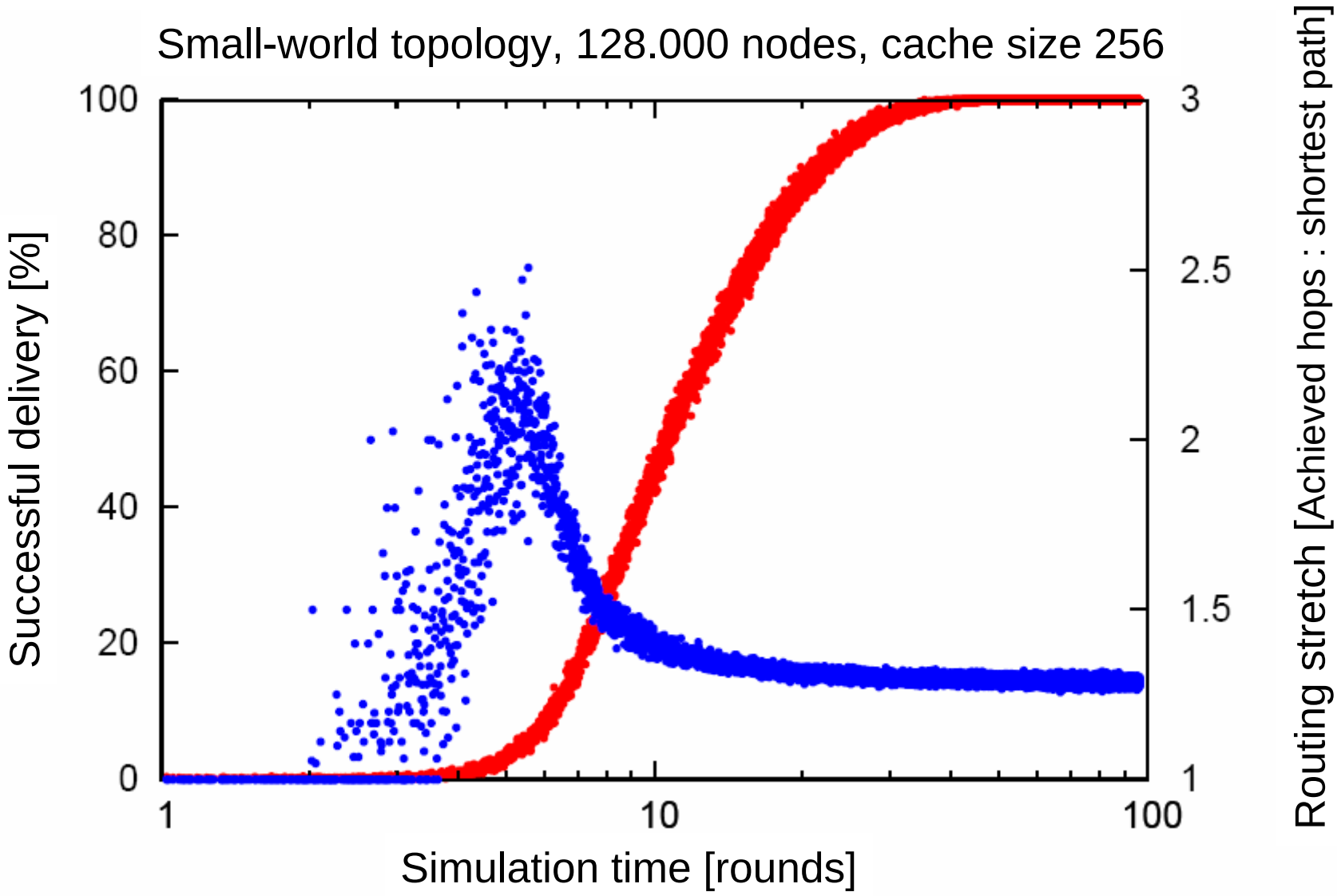
51	101	29	97	3	42	13

13	29	101	51

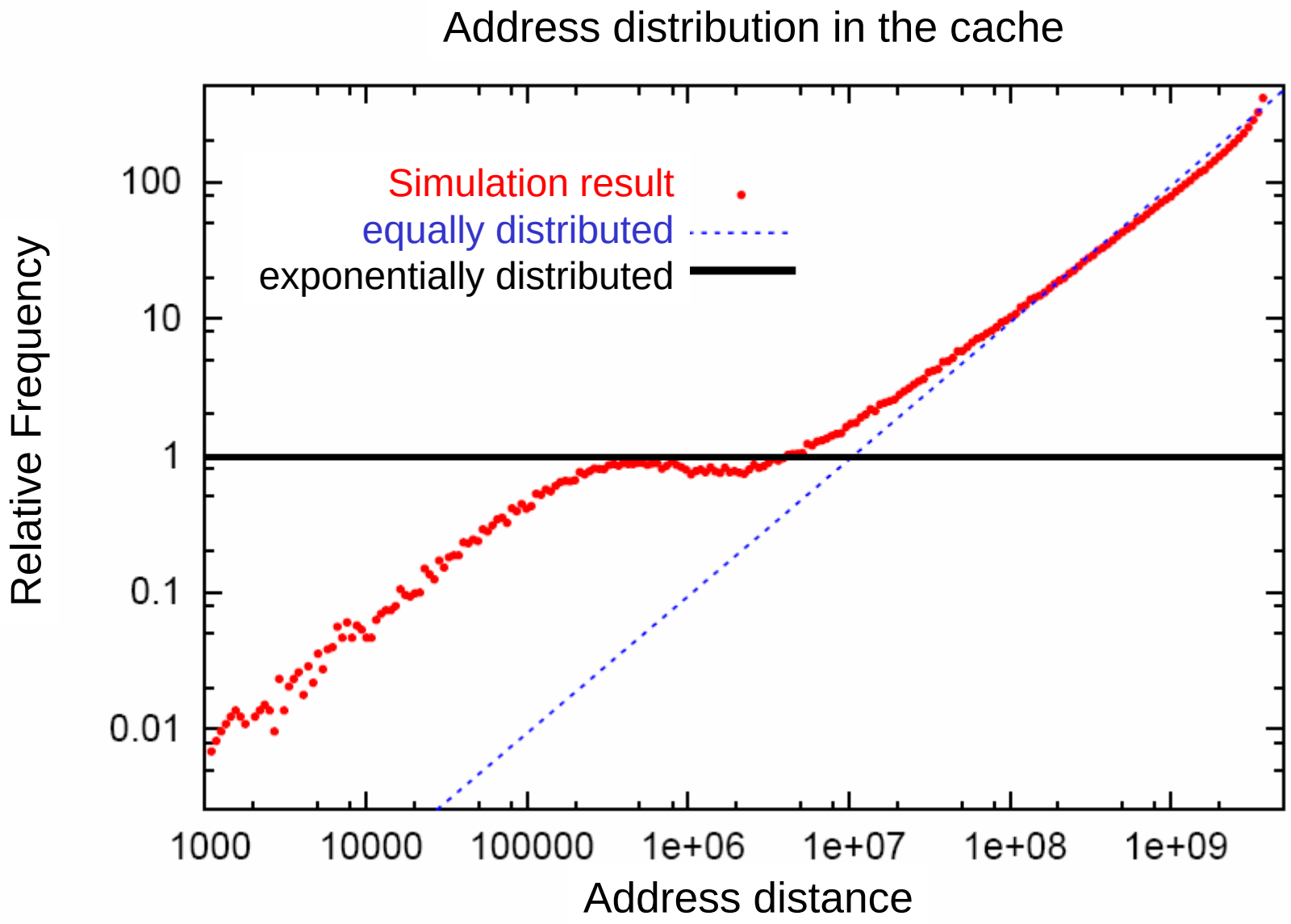




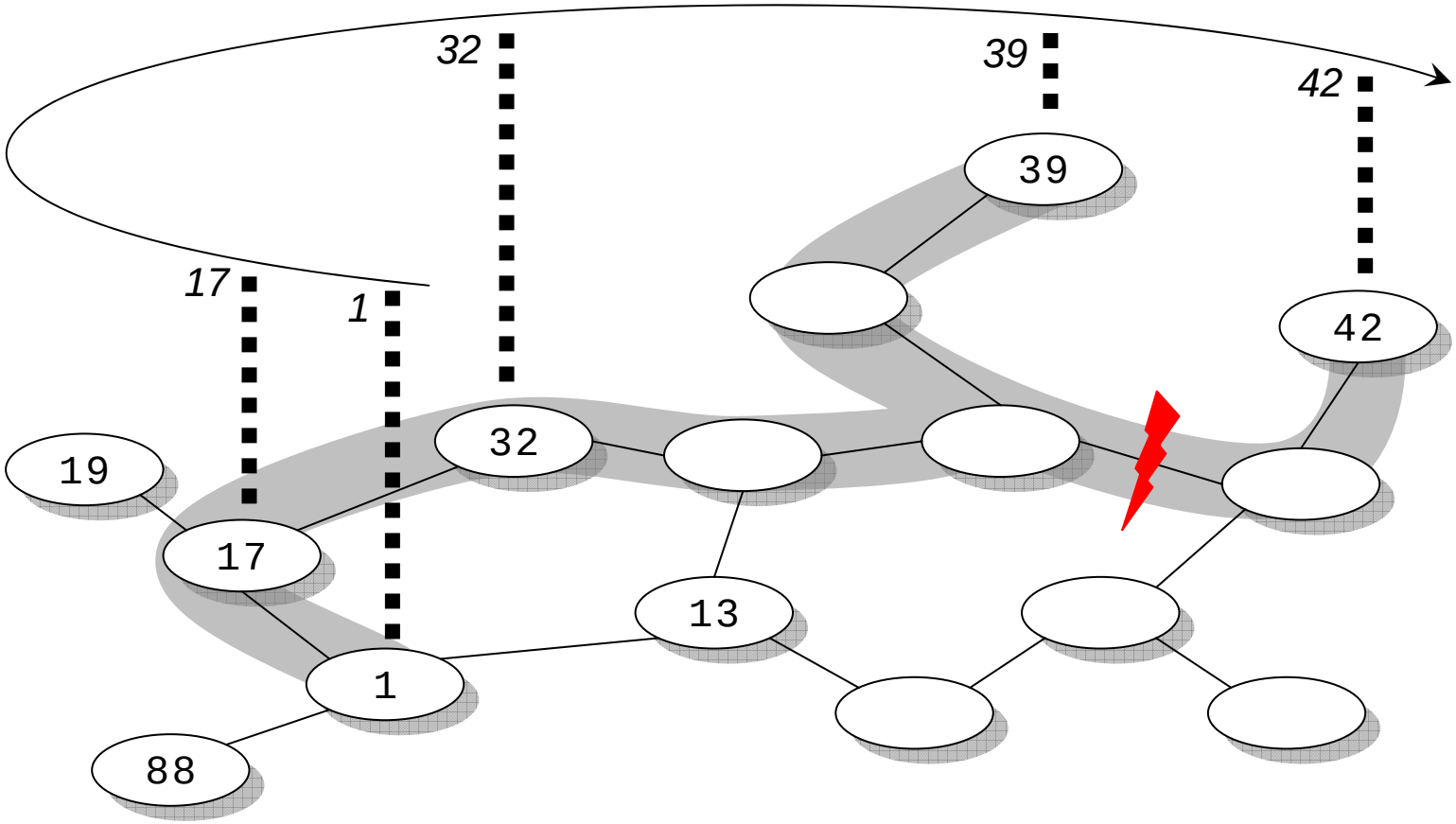
Simulation Results (1) – Consistency



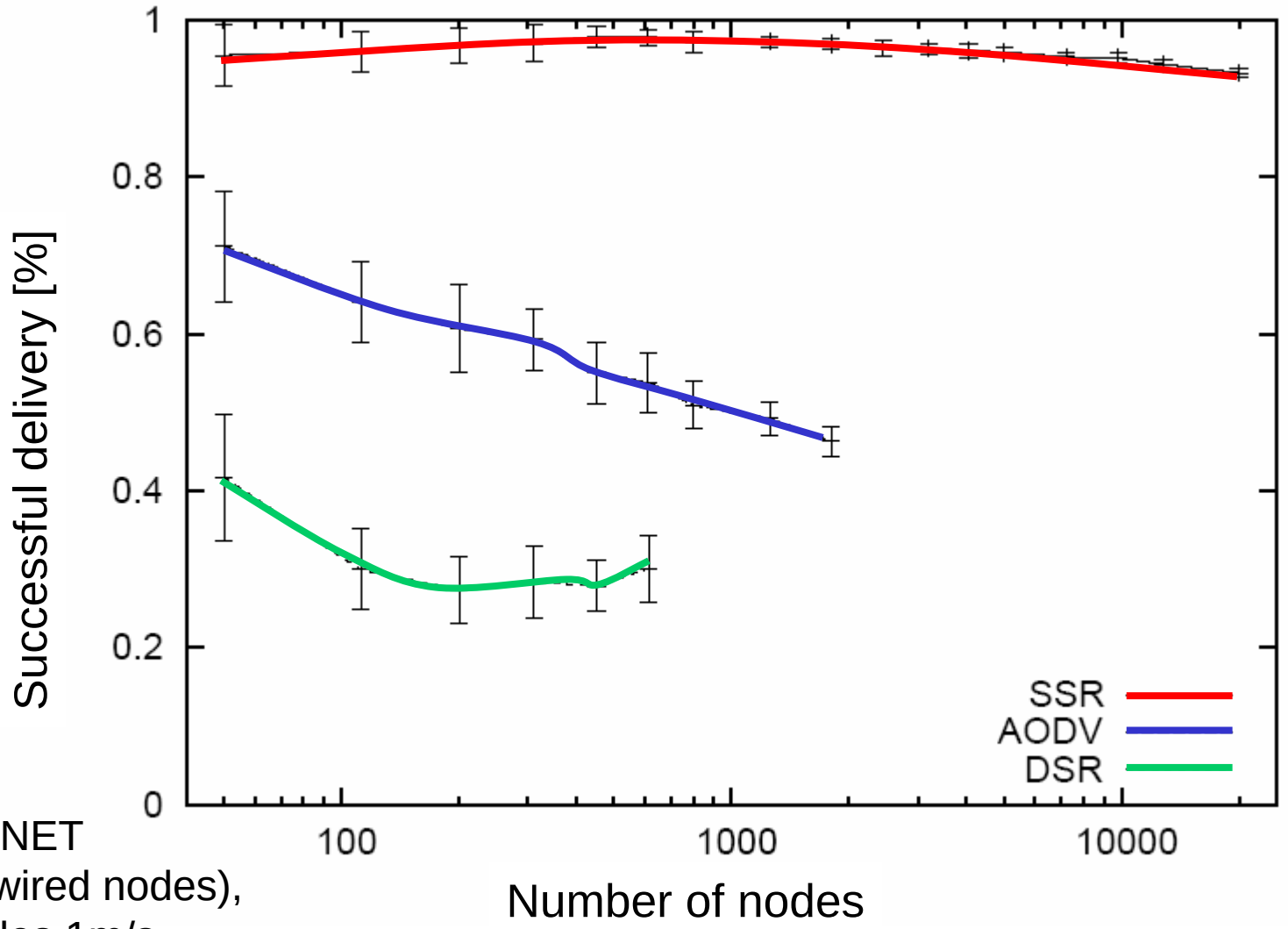
Simulation Results (2) – Node Specialization



Dealing with Churn and Mobility

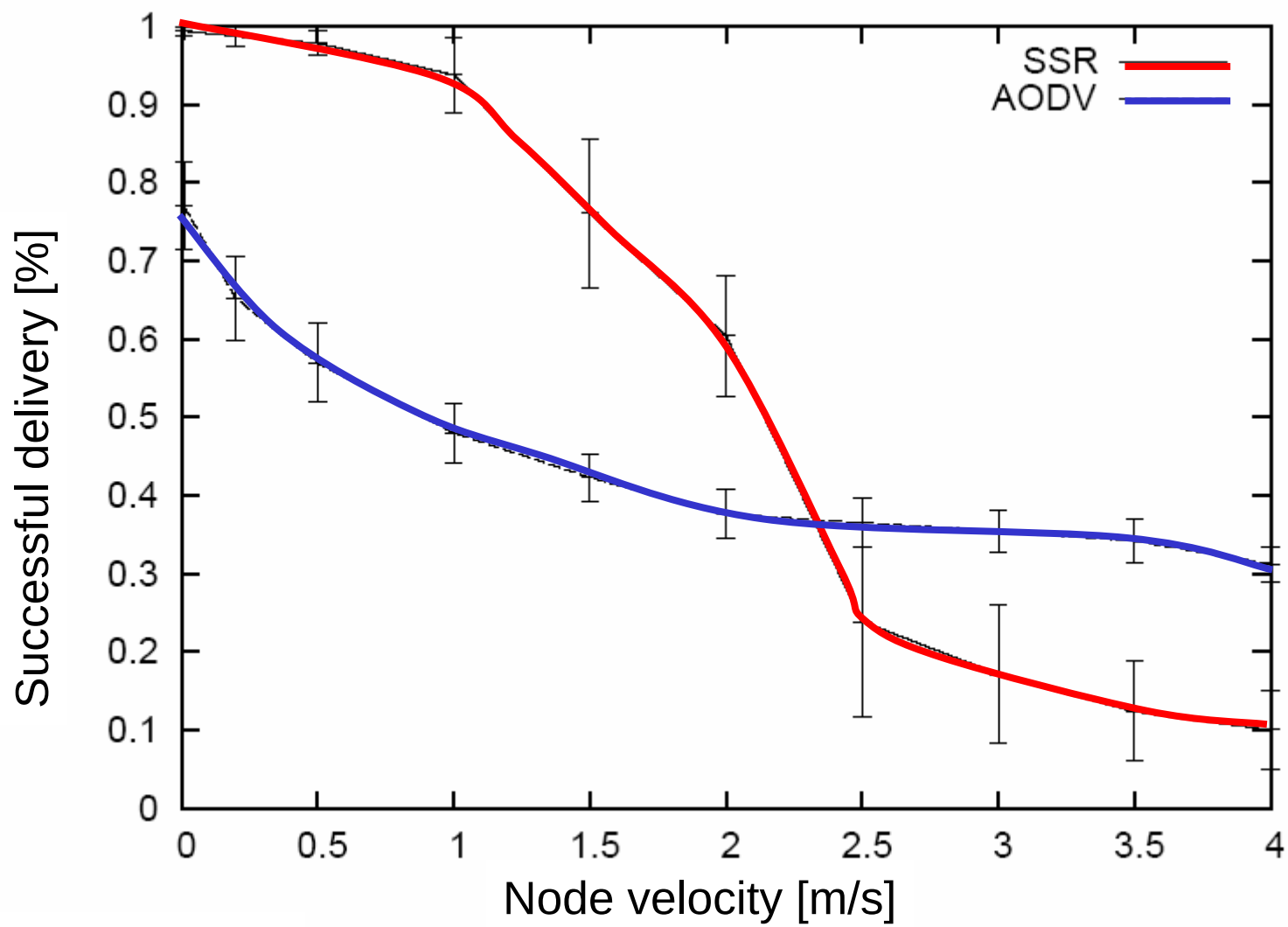


Simulation (3) – Compare to AODV and DSR



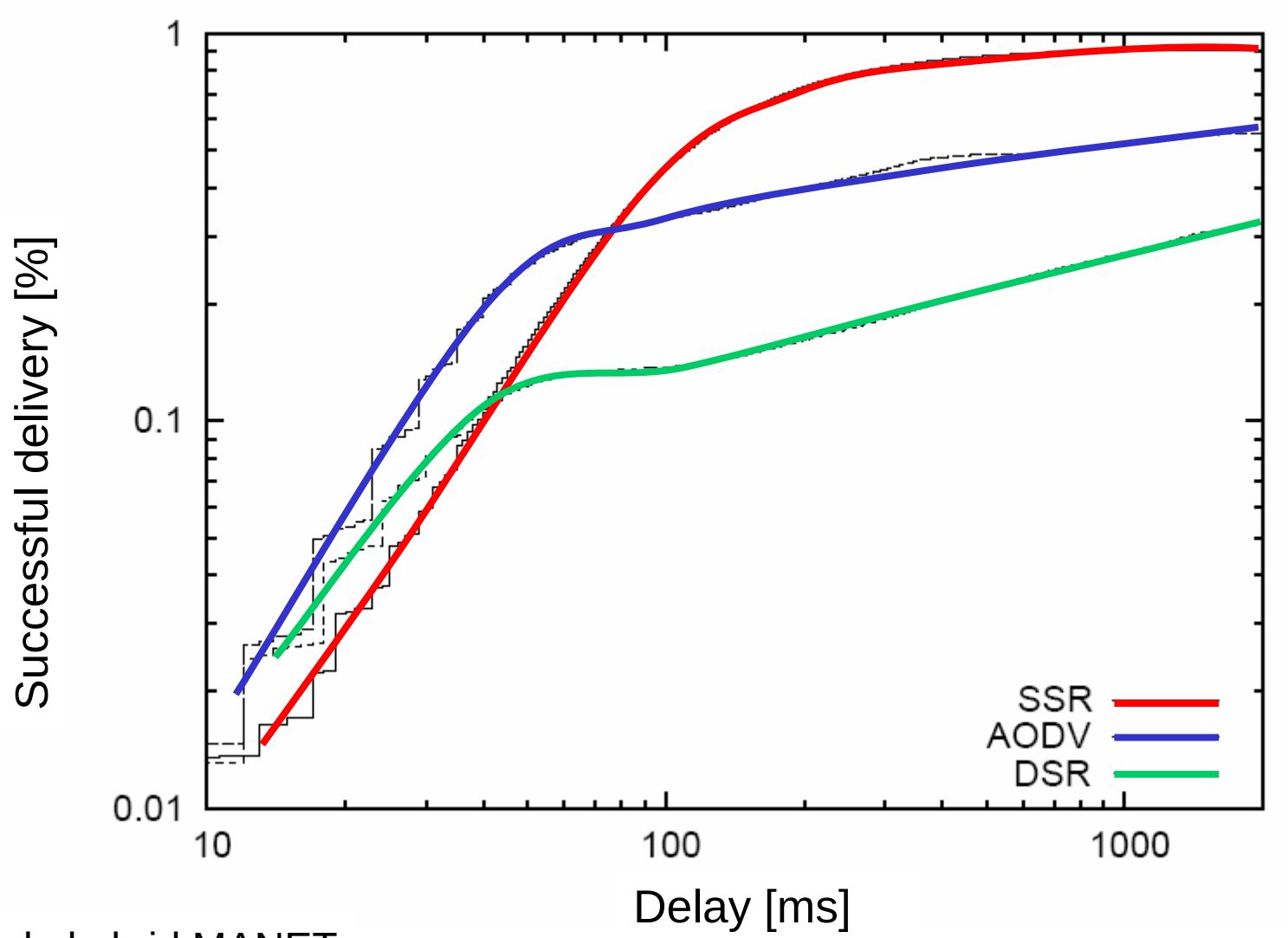
Hybrid MANET
(5% fixed wired nodes),
Mobile nodes 1m/s

Simulation Results (4) – Node velocity



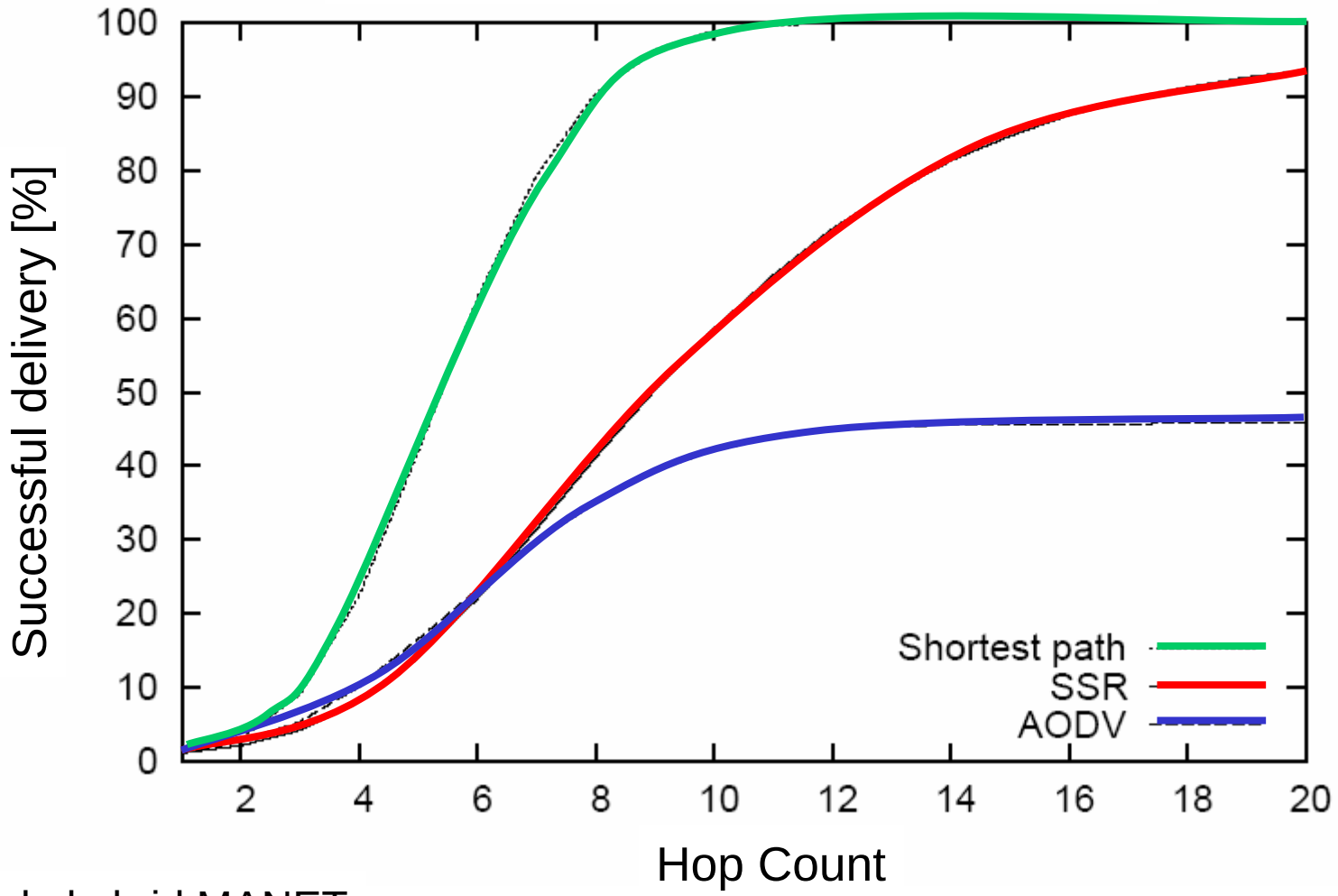
450 node pure MANET

Simulation Results (5) – Delay distribution



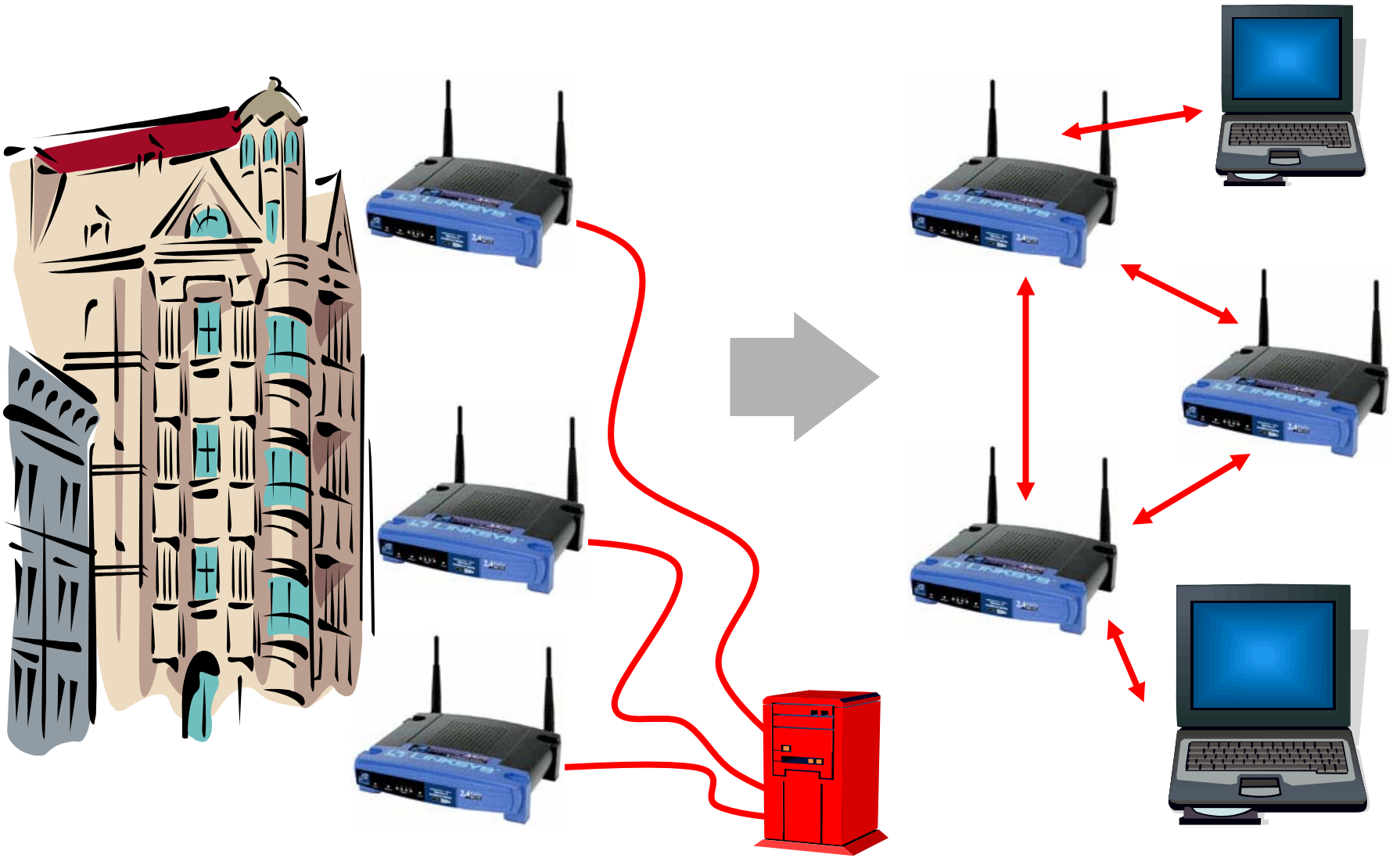
612 node hybrid MANET

Simulation Results (6) – Hop distribution



800 node hybrid MANET

The Linyphi Mesh Network for IPv6



Scalable Source Routing – Summary

Seven simple rules lead to self-organized routing:

- Register with your successor in the virtual ring.
- Update your predecessor if necessary.
- (Flood only if you think to have the globally greatest address.)
- Cache paths in a LRU manner.
- Prune paths when appending paths & keep shorter path variants in the cache.
- Upon cache miss, forward to the node that is physically closest and virtually farthest (=Chord rule).
- Upon detection of broken path, notify last intermediate node.

This leads to

- Much smaller memory requirement compared to Dijkstra and Bellman-Ford.
- Much less control messages compared to flooding.
- Works in arbitrary topologies (unlike geographical routing).
- Better delivery ratios than AODV (when mobility less than 2m/s).

Thank you!

Questions?

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