Stateless Reliable Geocasting

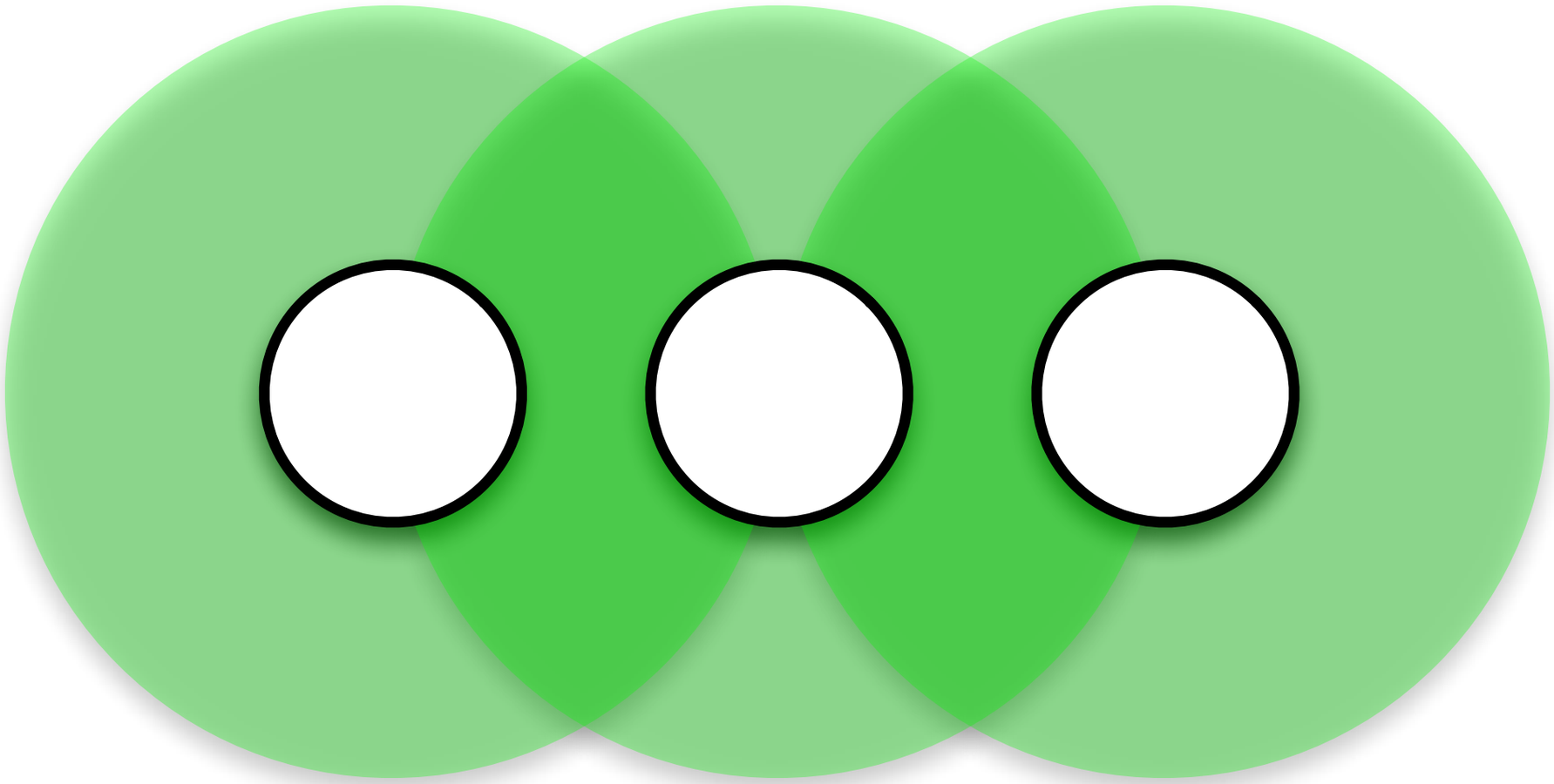
Jordan Adamek, James Scott Robinson,
Mikhail Nesterenko, **Sébastien Tixeuil**

SRDS, Hong Kong, September 27, 2017

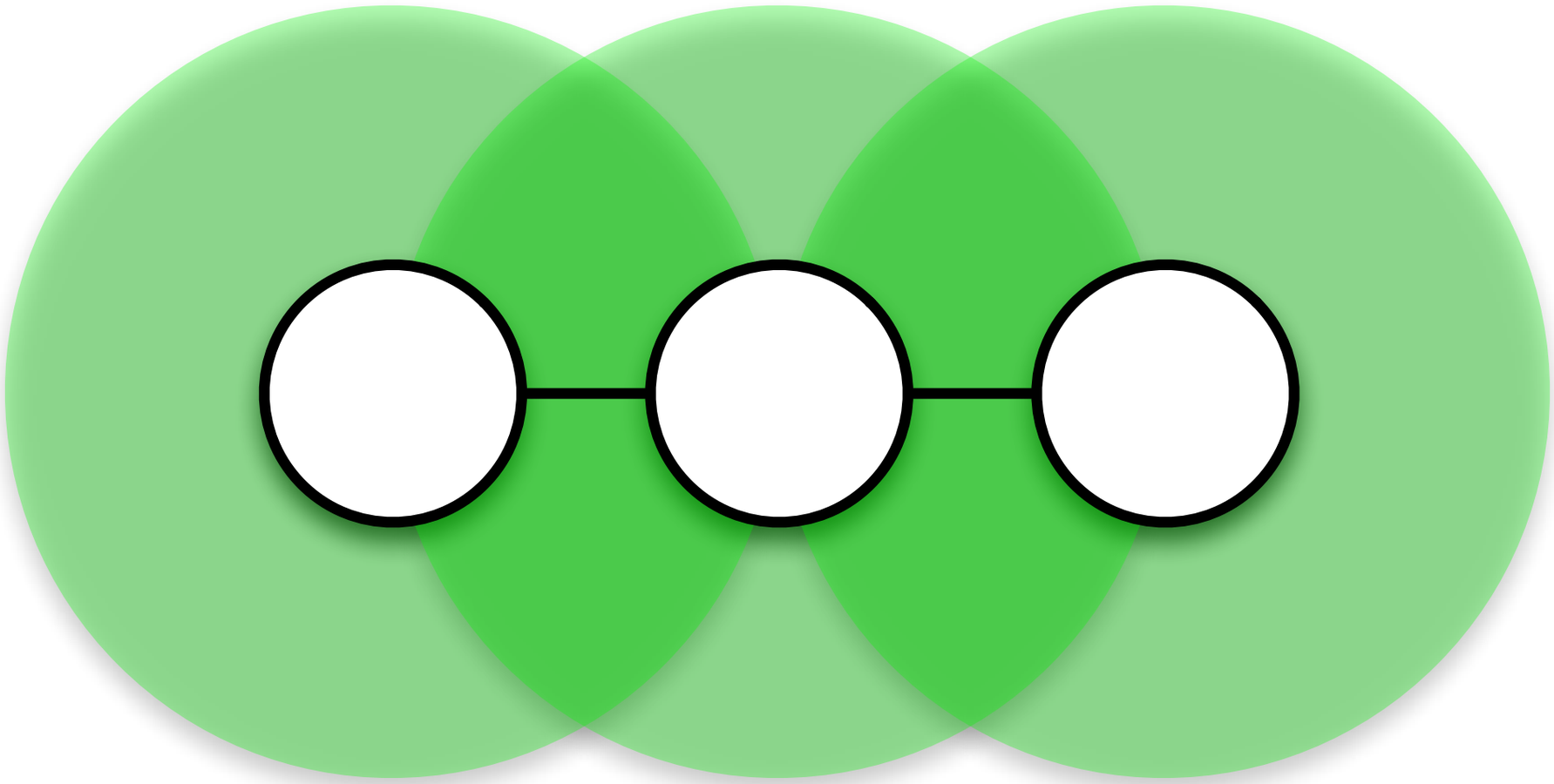
Context & Motivation

Wireless Sensor Networks

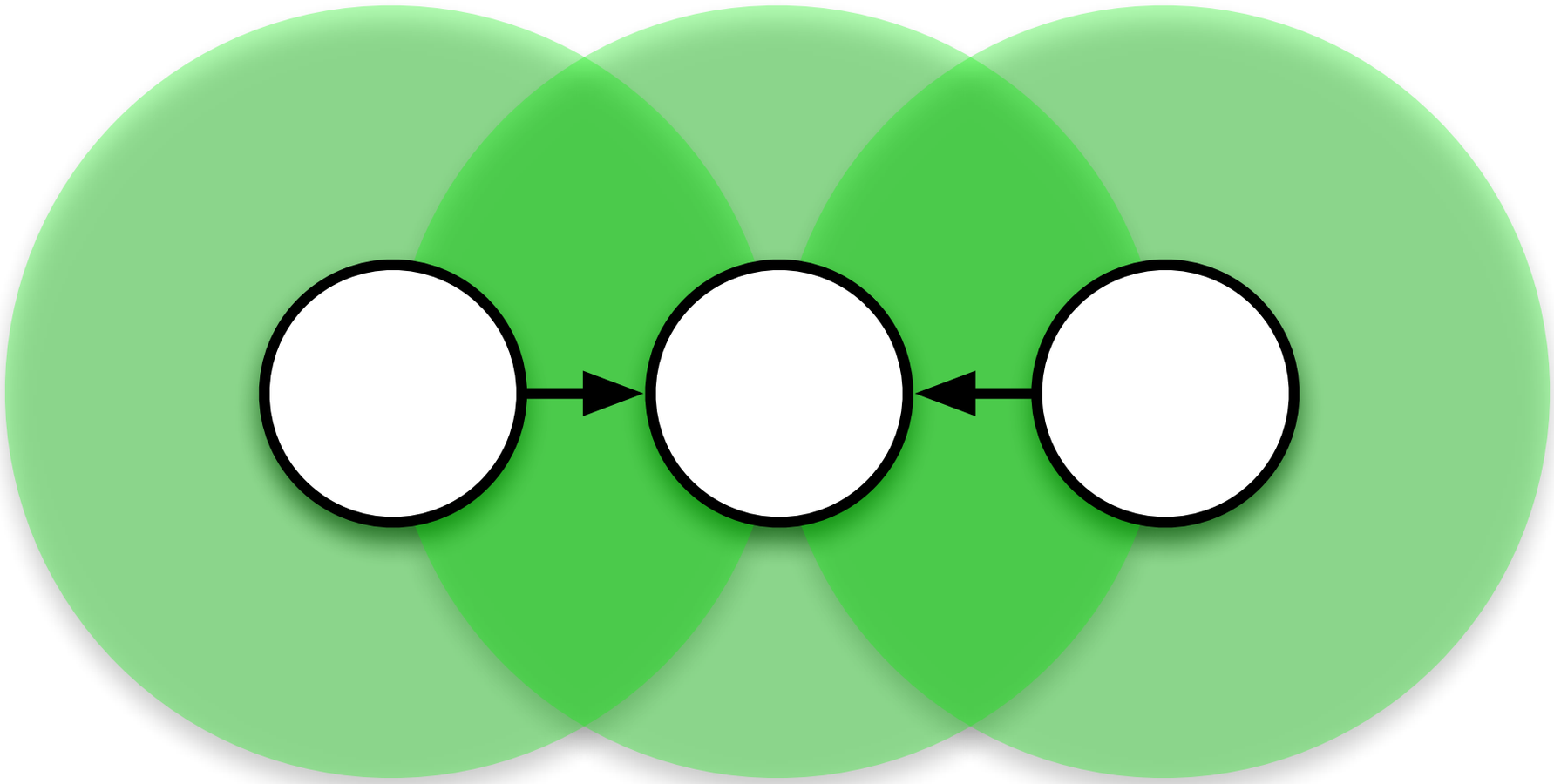
Wireless Sensor Networks



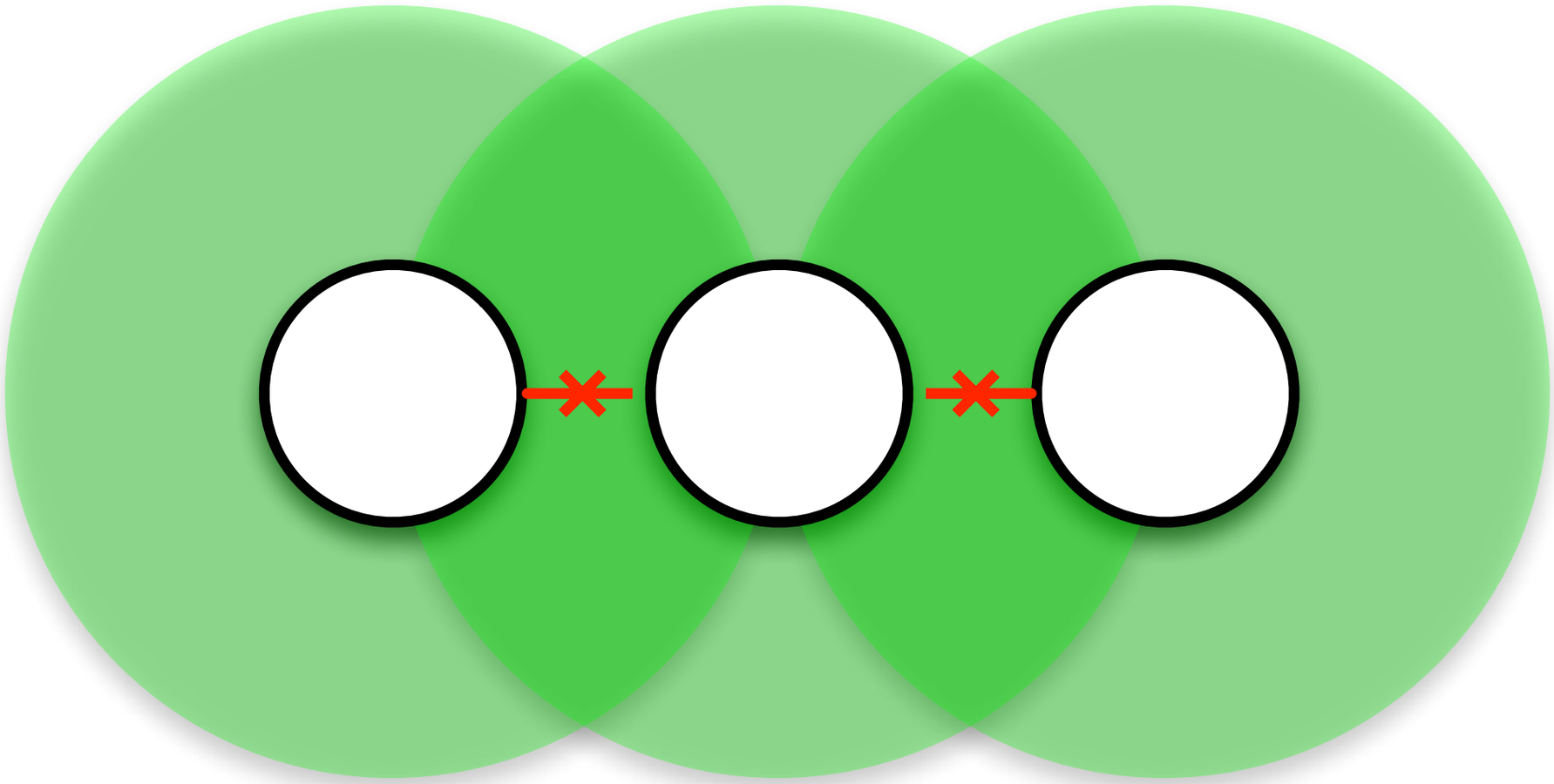
Wireless Sensor Networks



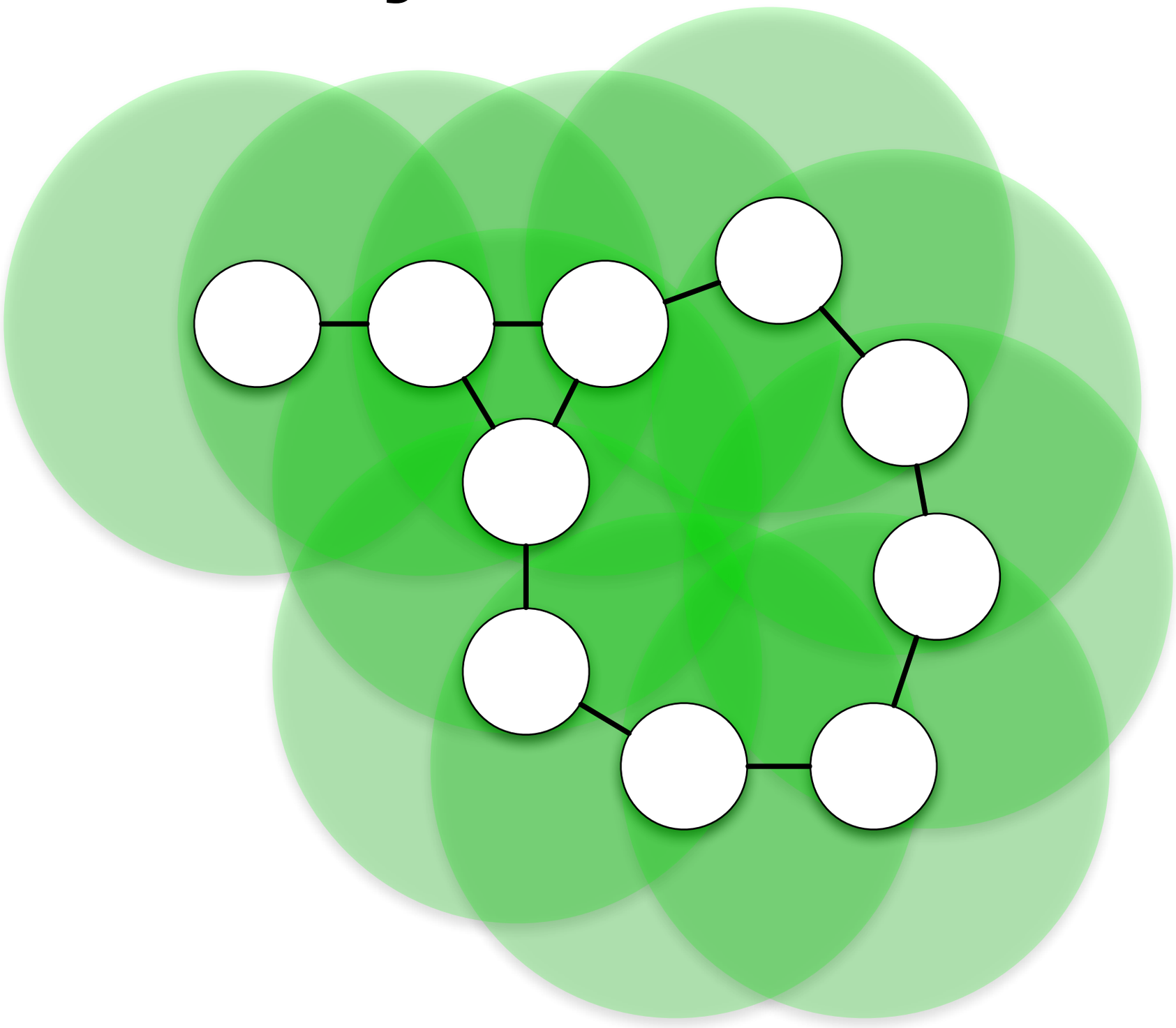
Reliability vs. Redundancy



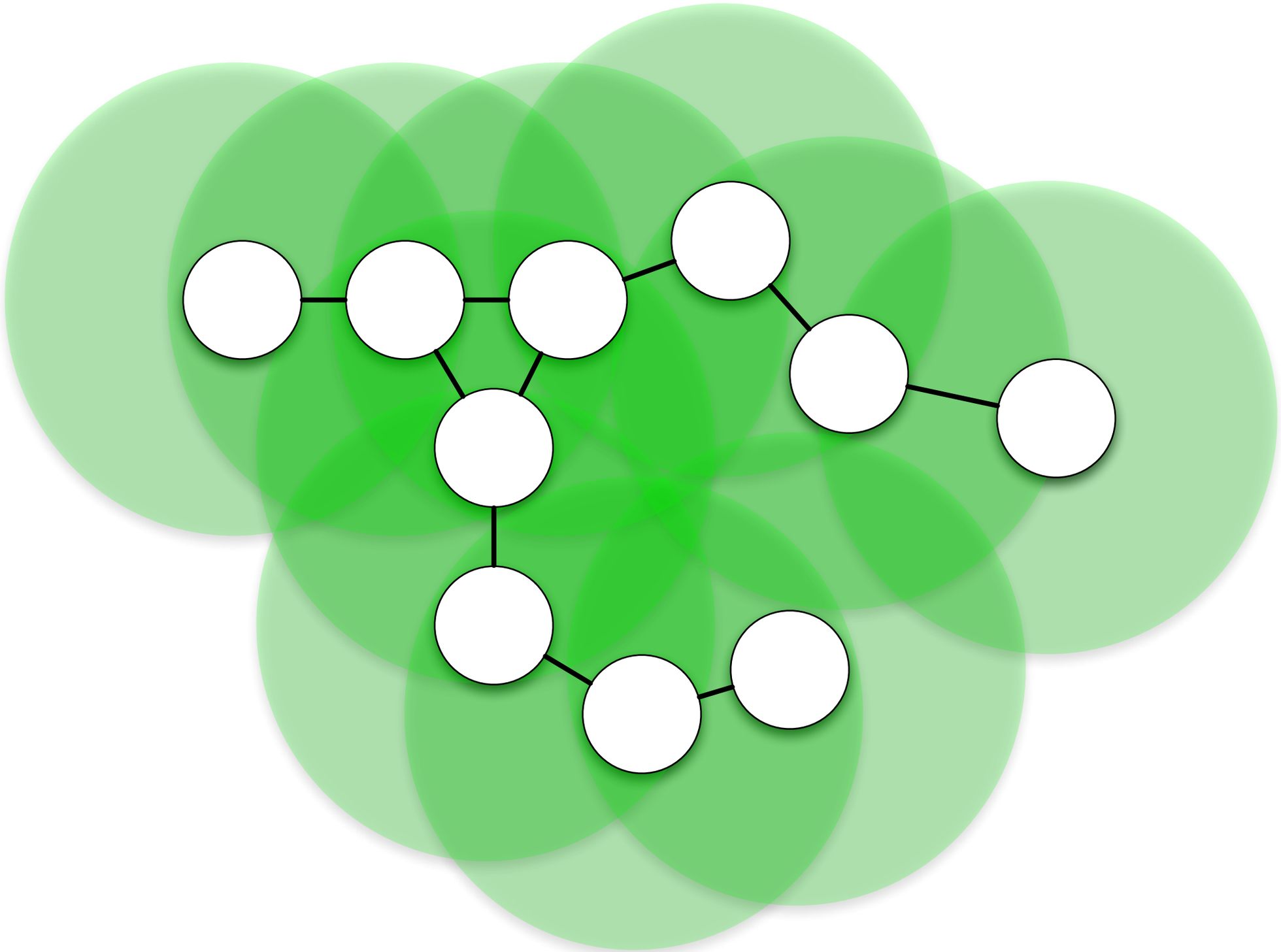
Reliability vs. Redundancy



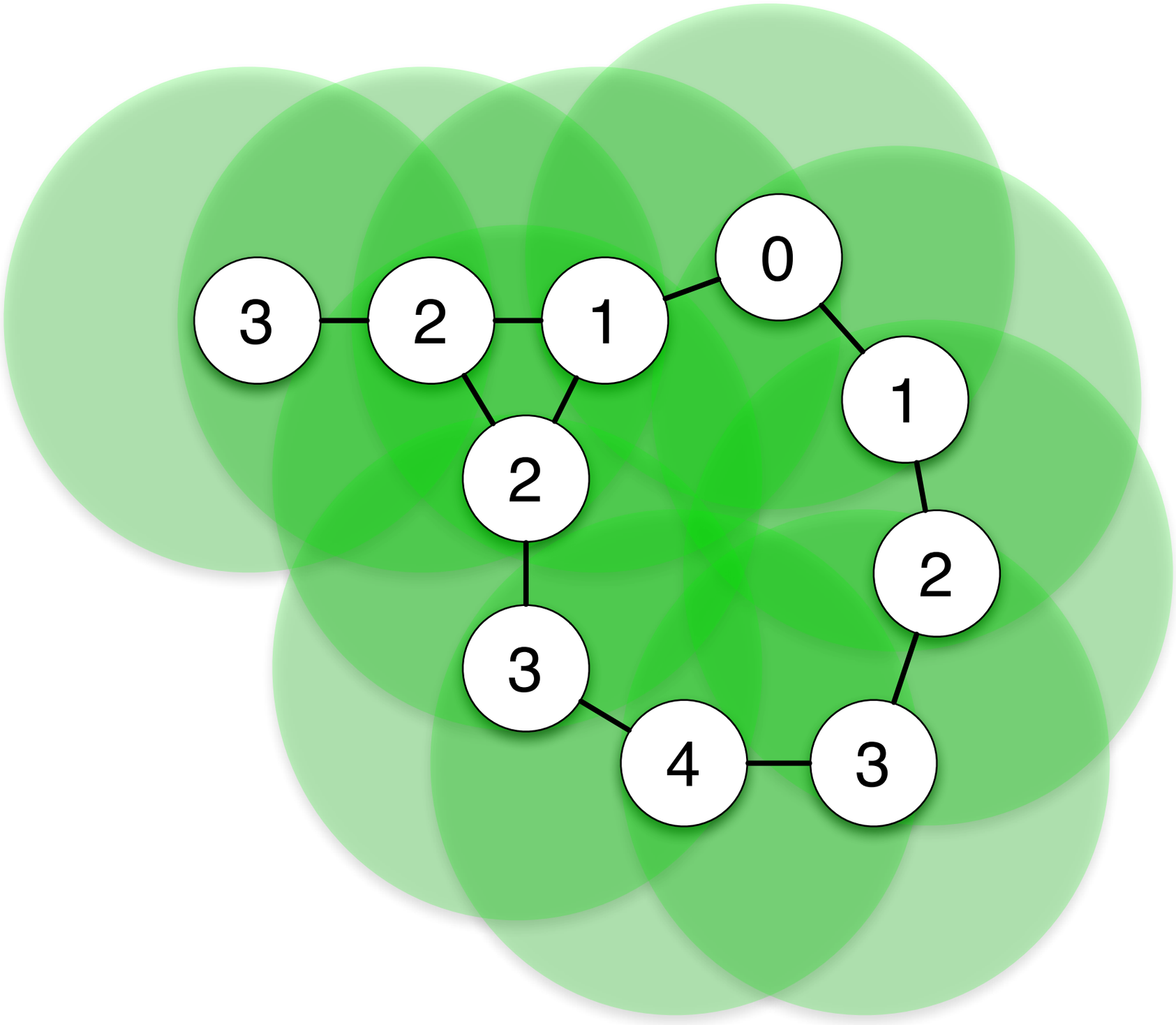
Dynamicity vs. Global State



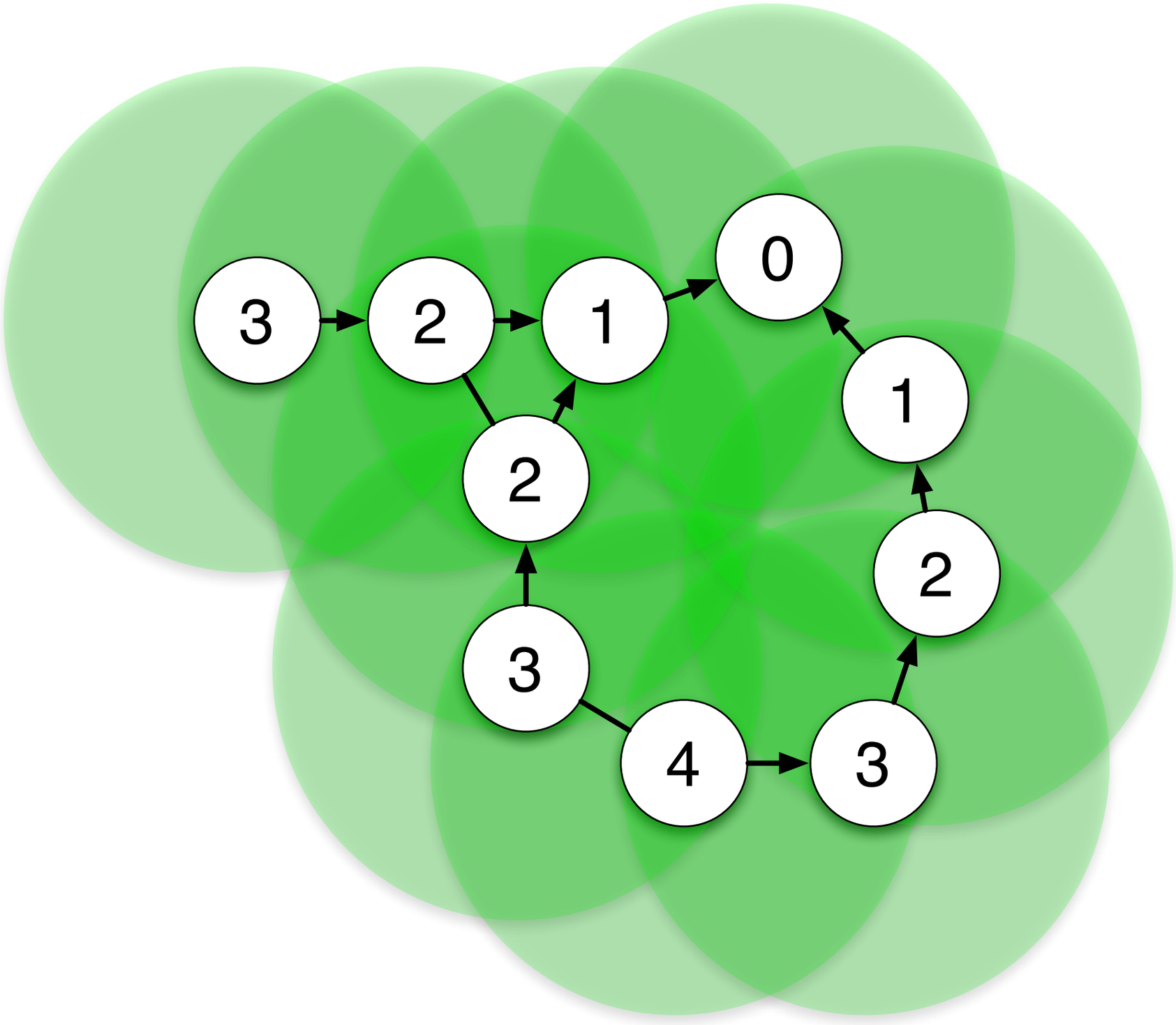
Dynamicity vs. Global State



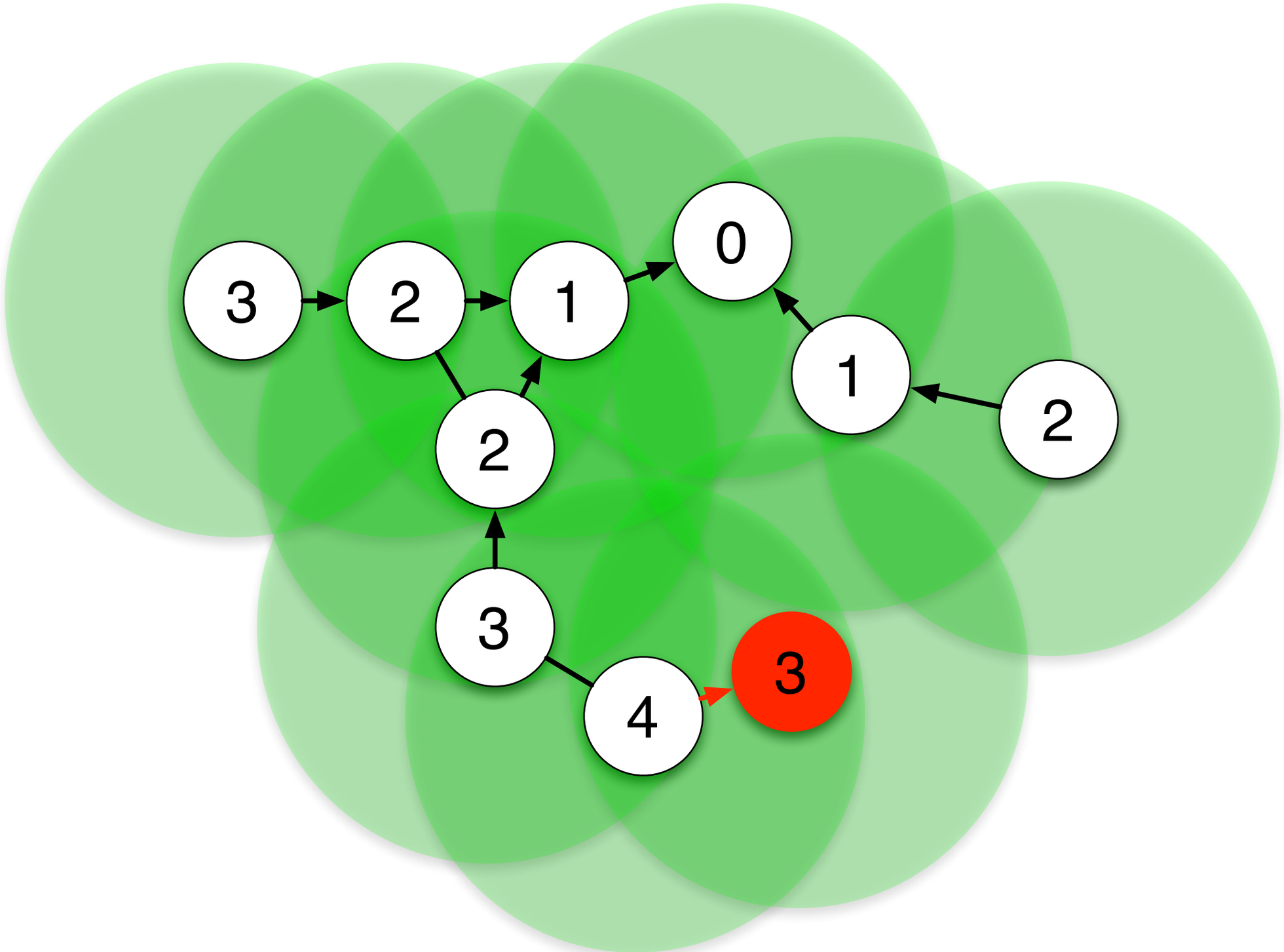
Dynamicity vs. Global State



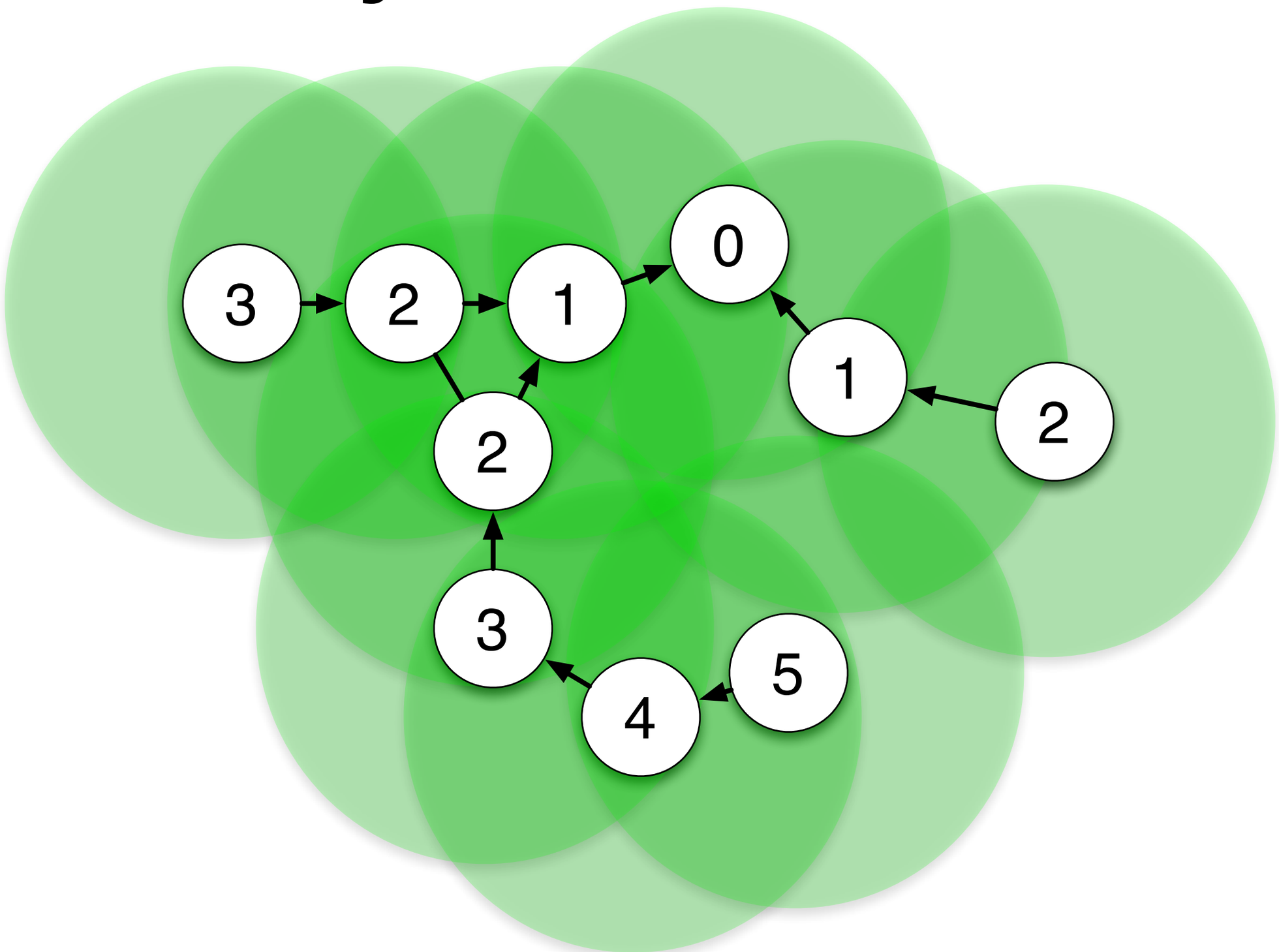
Dynamicity vs. Global State



Dynamicity vs. Global State



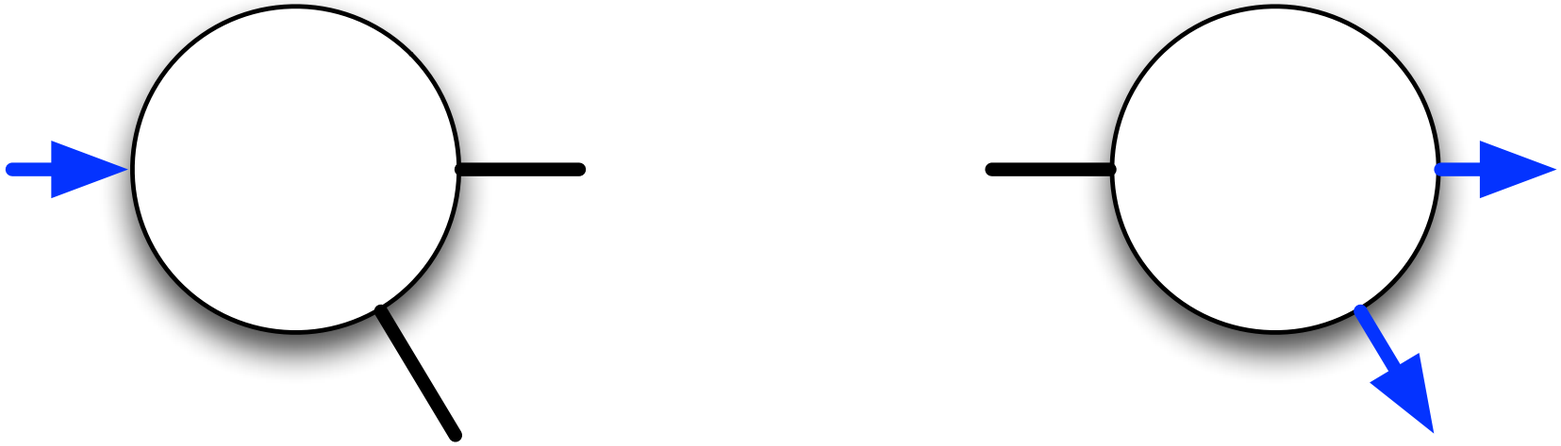
Dynamicity vs. Global State



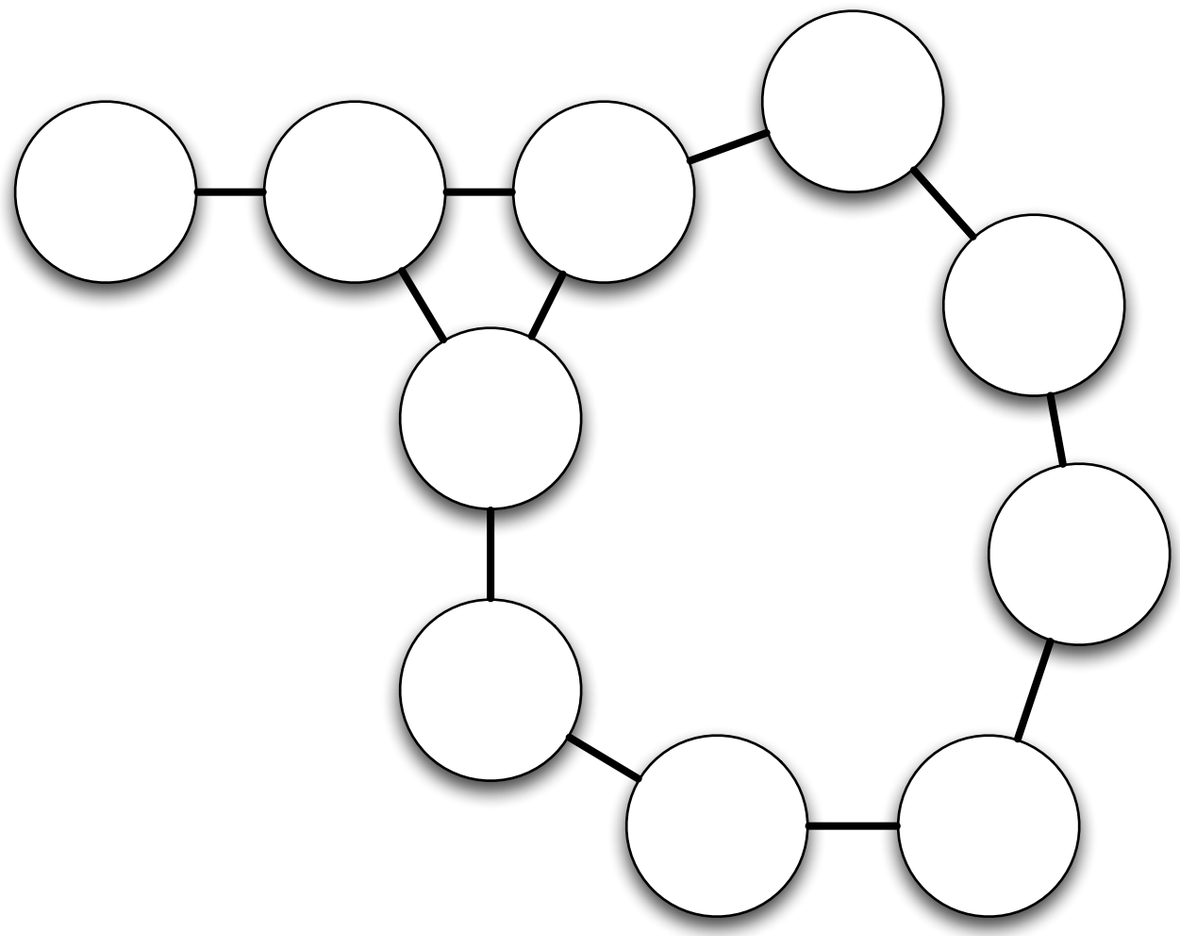
Stateless Routing

A routing algorithm is **stateless** if it is designed such that devices store *no information* about messages *between transmissions*. It is **stateful** otherwise.

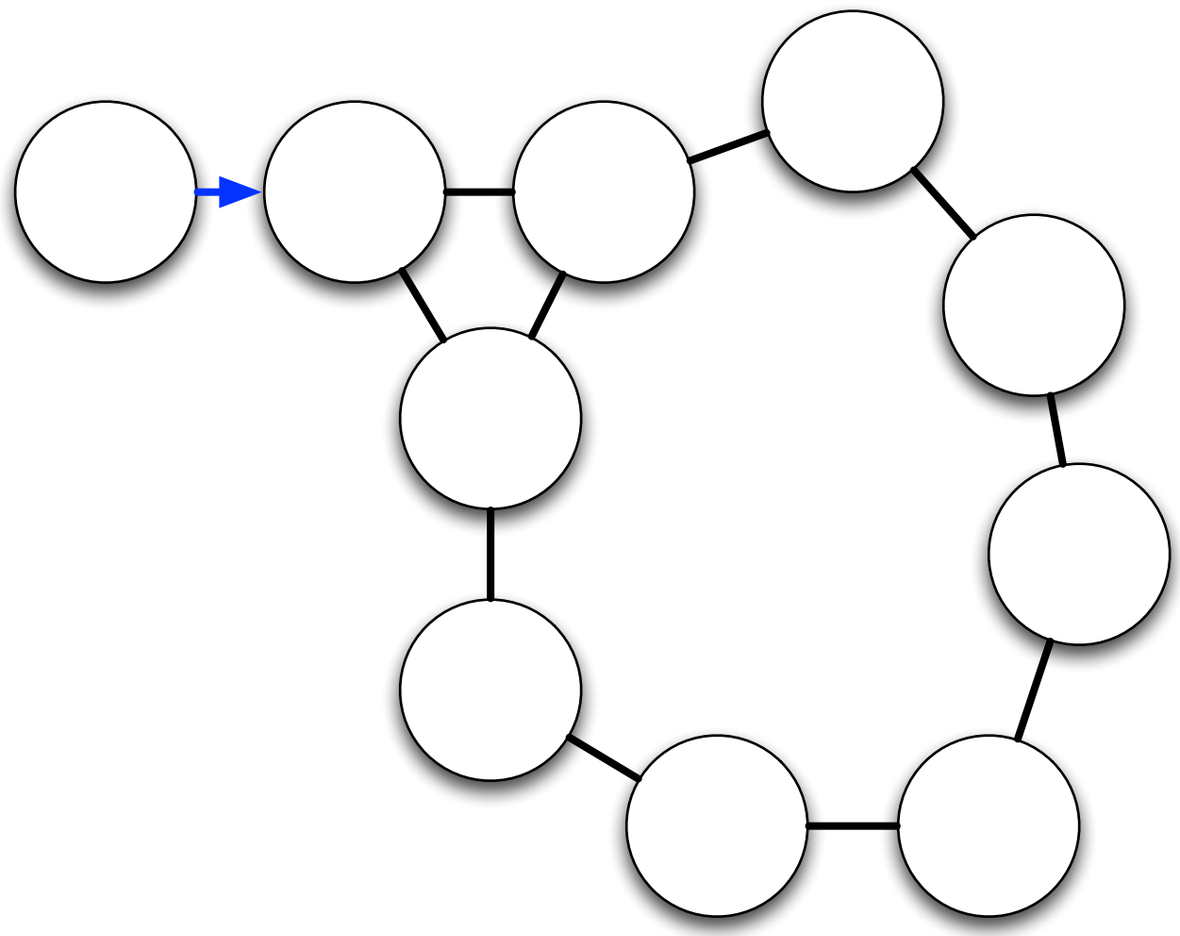
Flooding



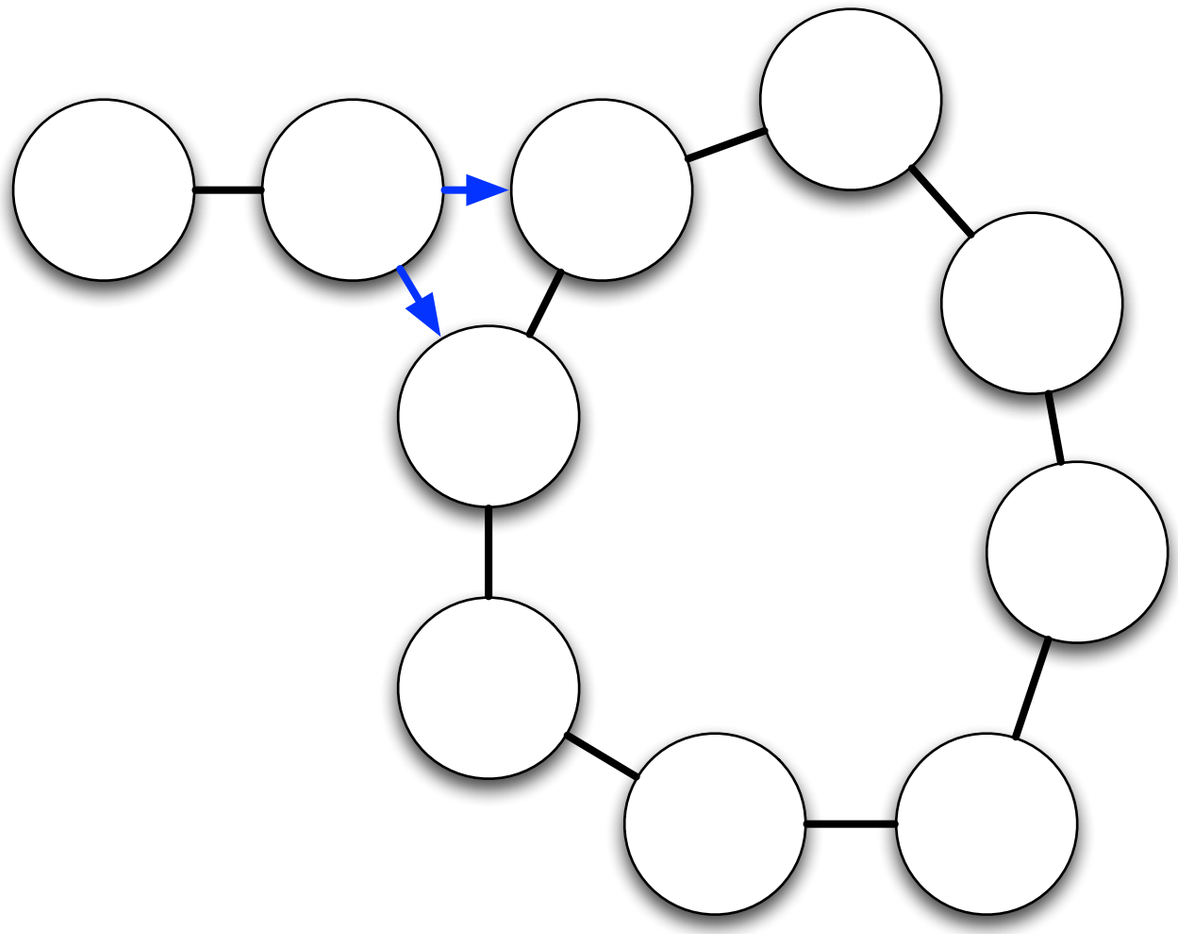
Stateless Flooding



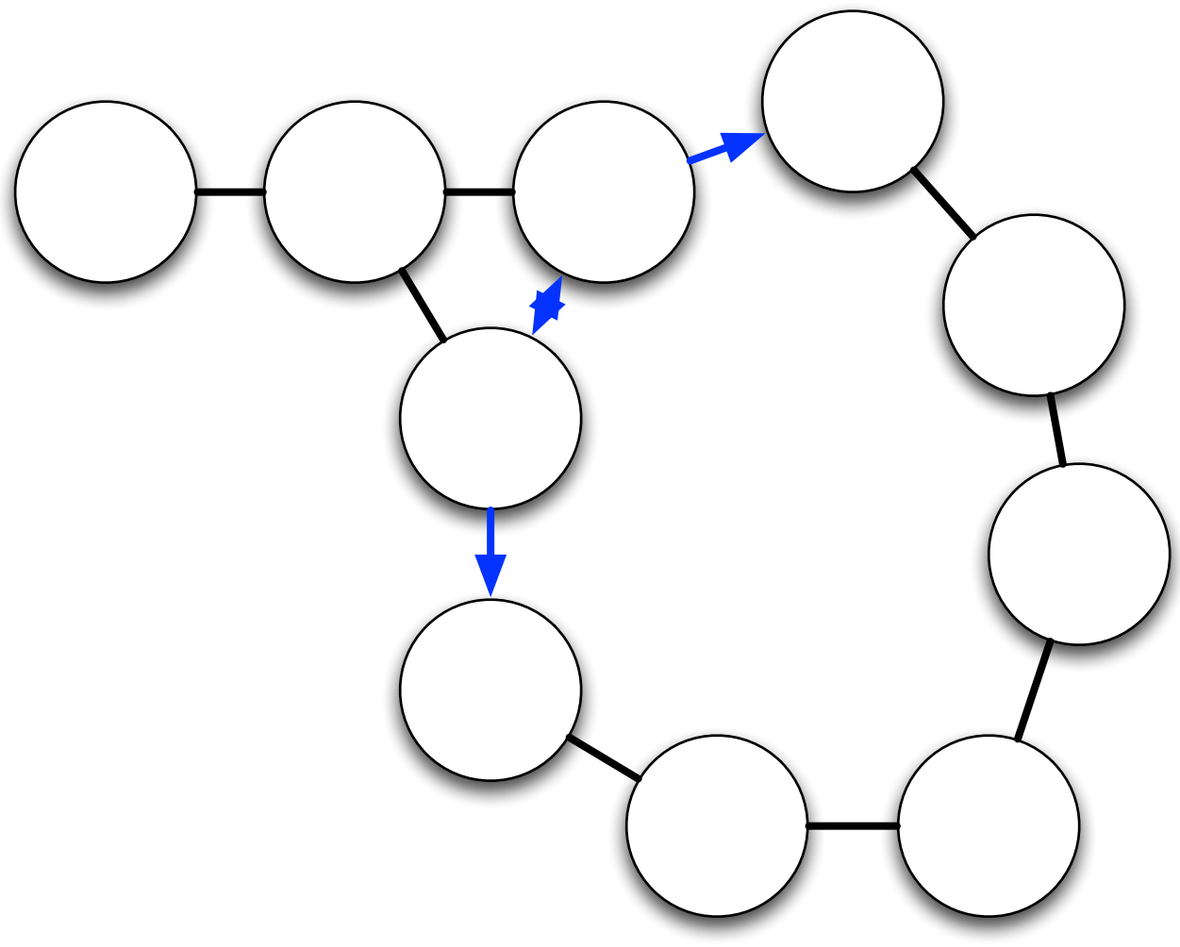
Stateless Flooding



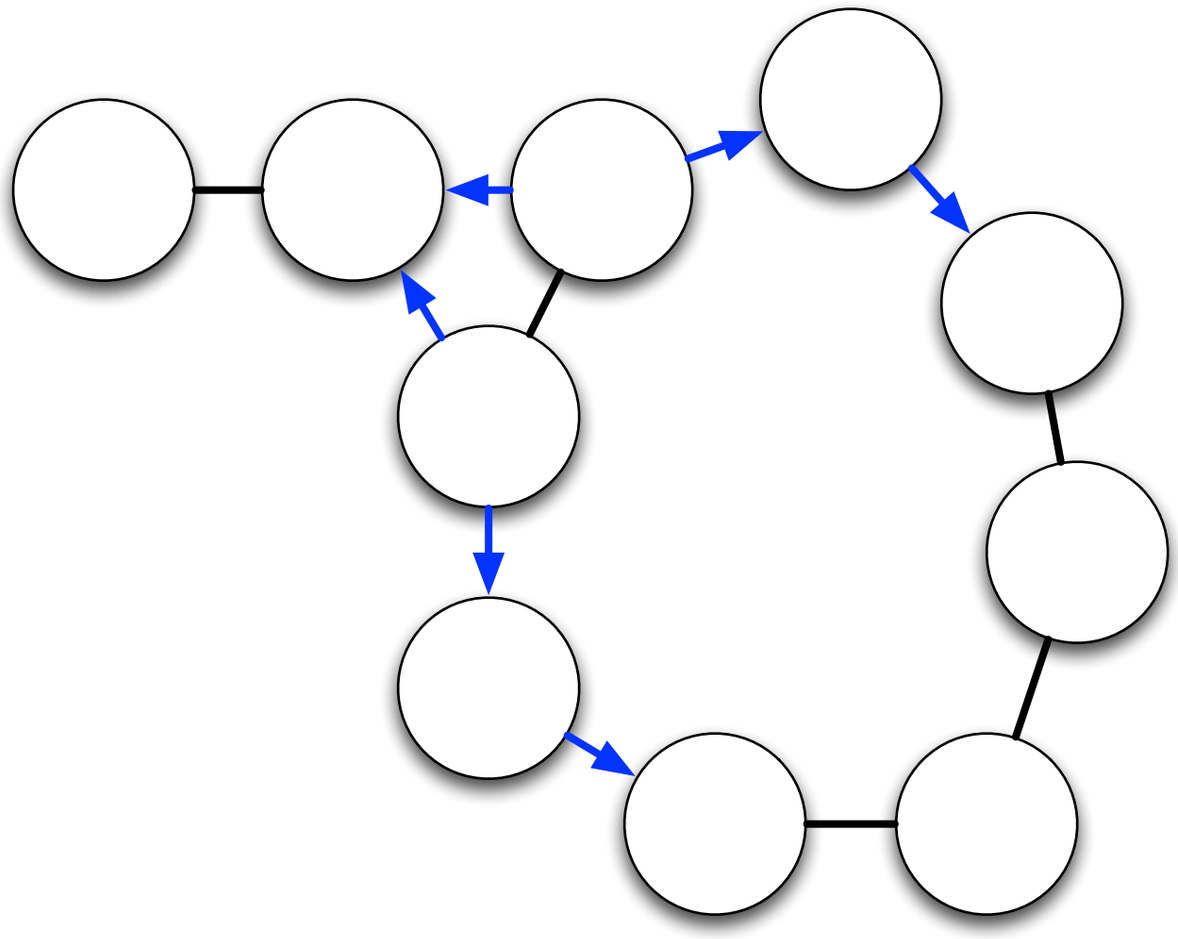
Stateless Flooding



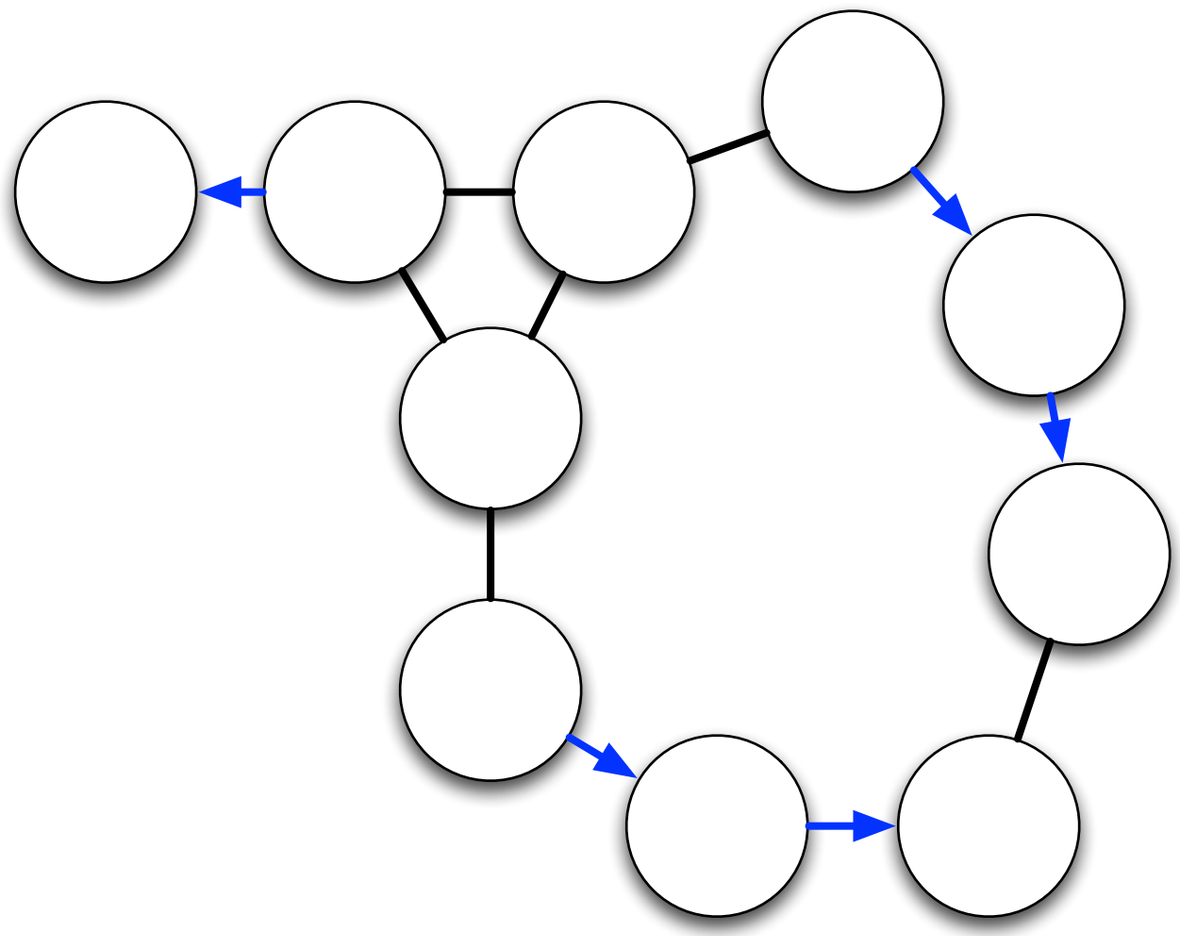
Stateless Flooding



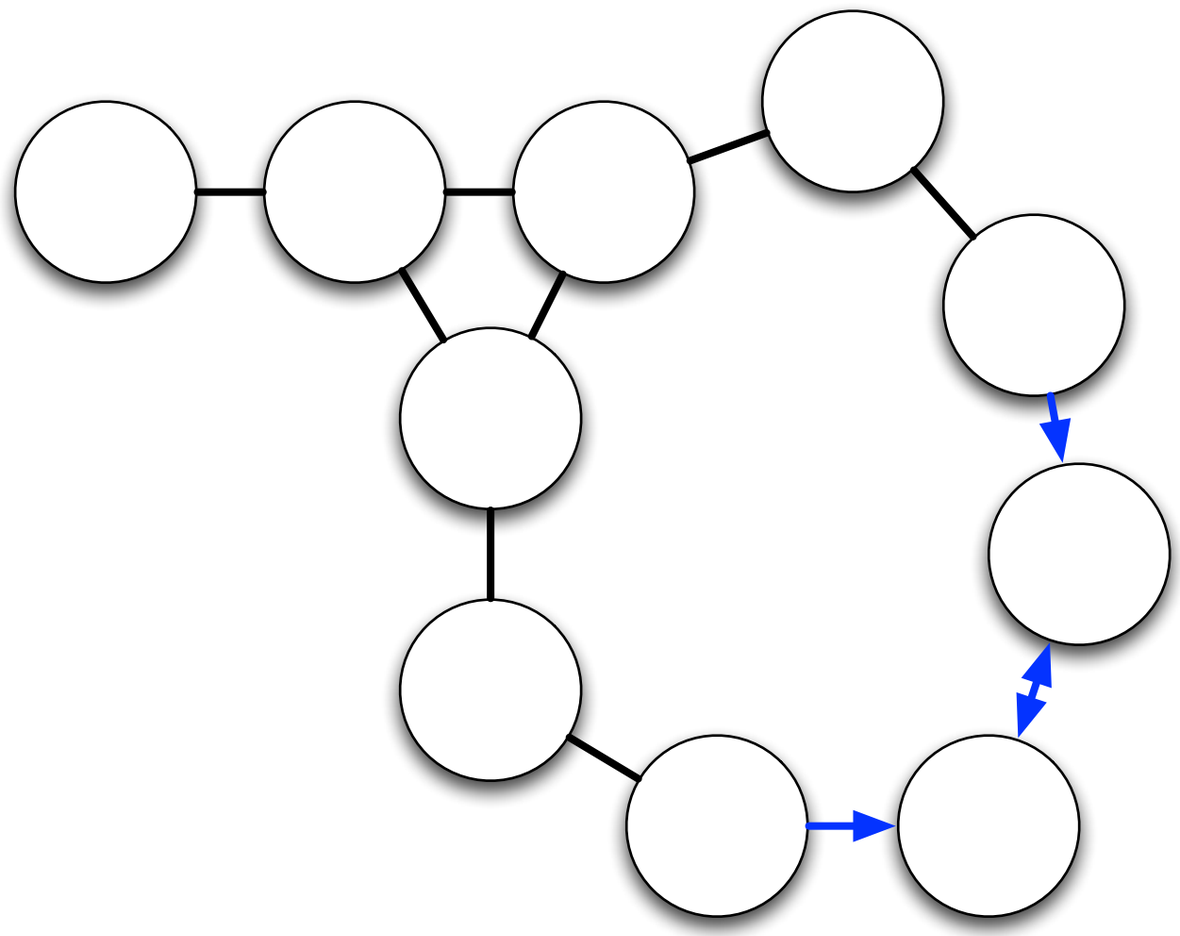
Stateless Flooding



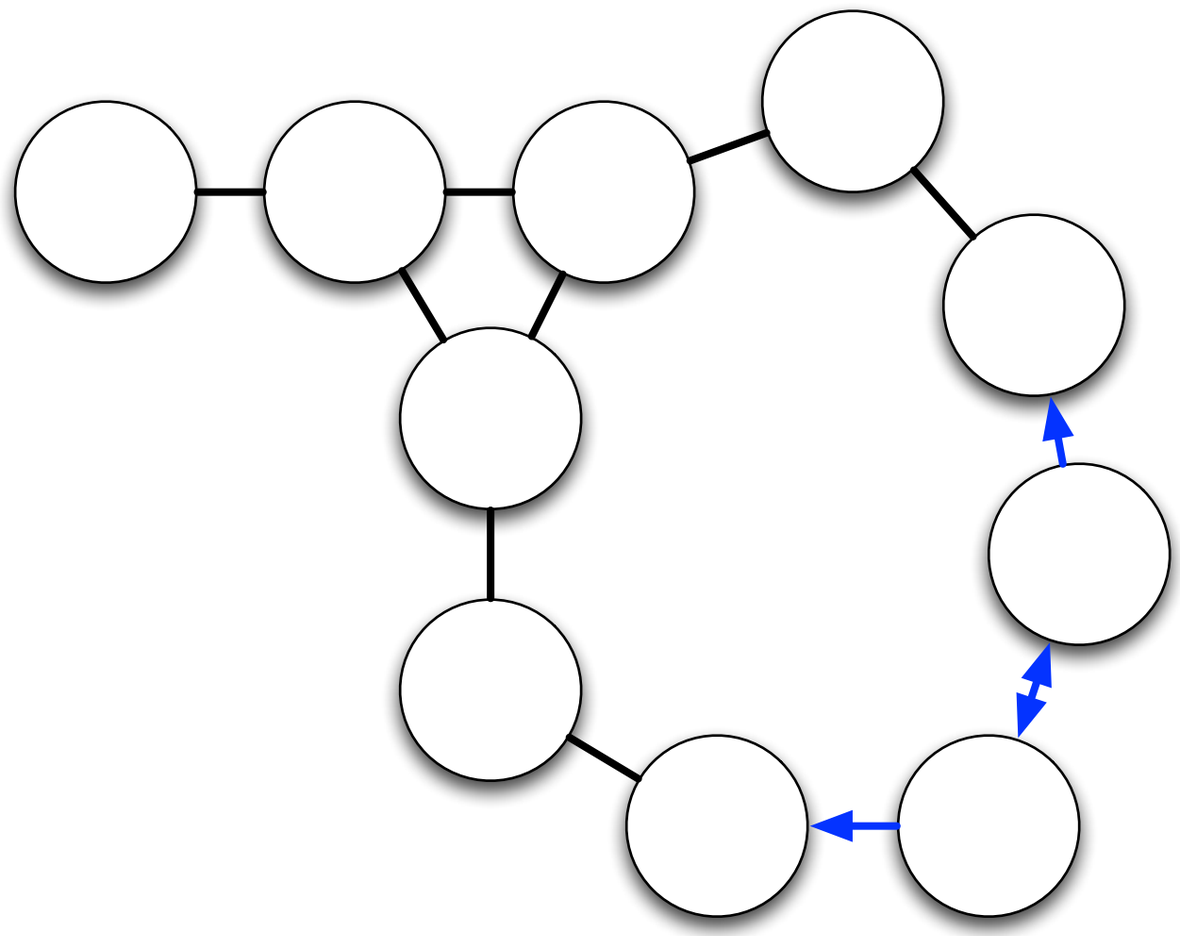
Stateless Flooding



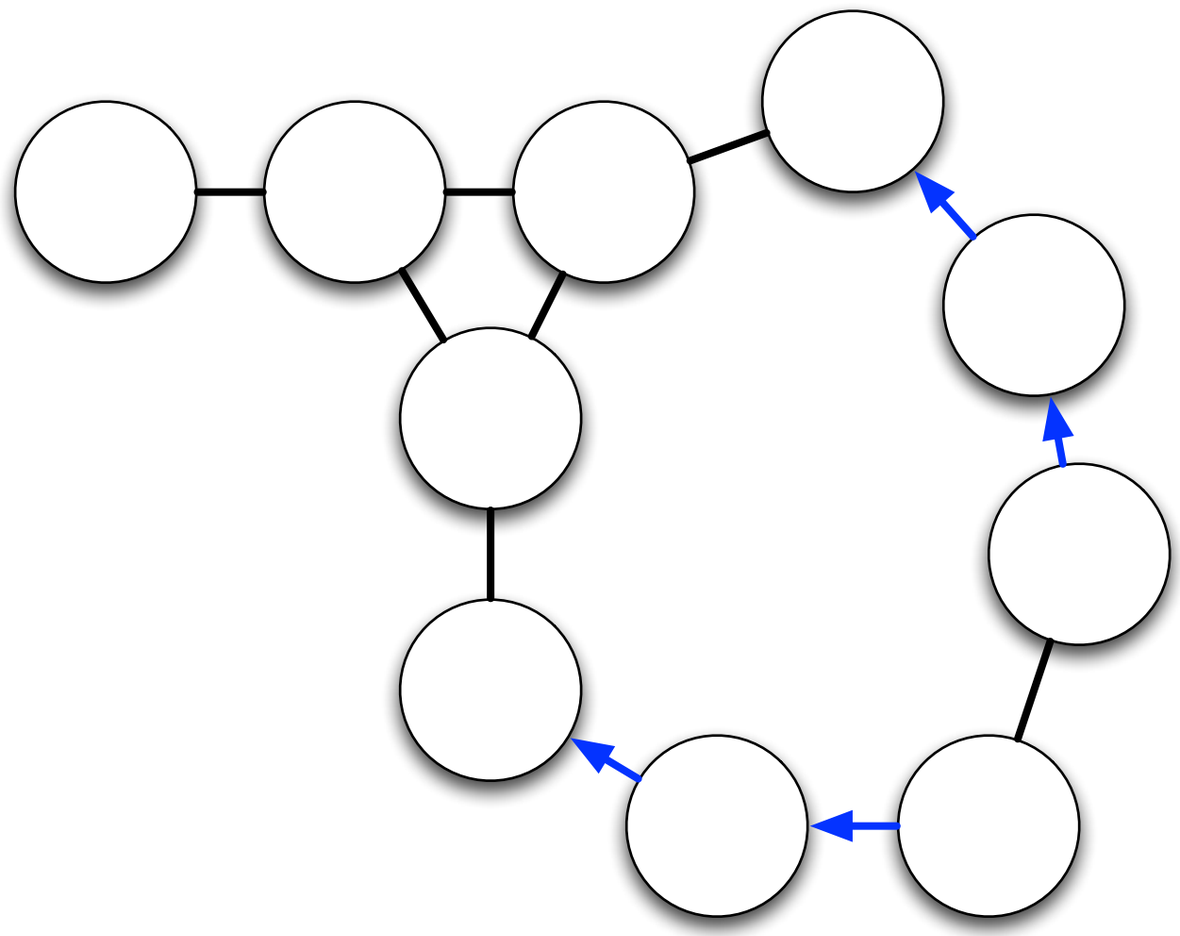
Stateless Flooding



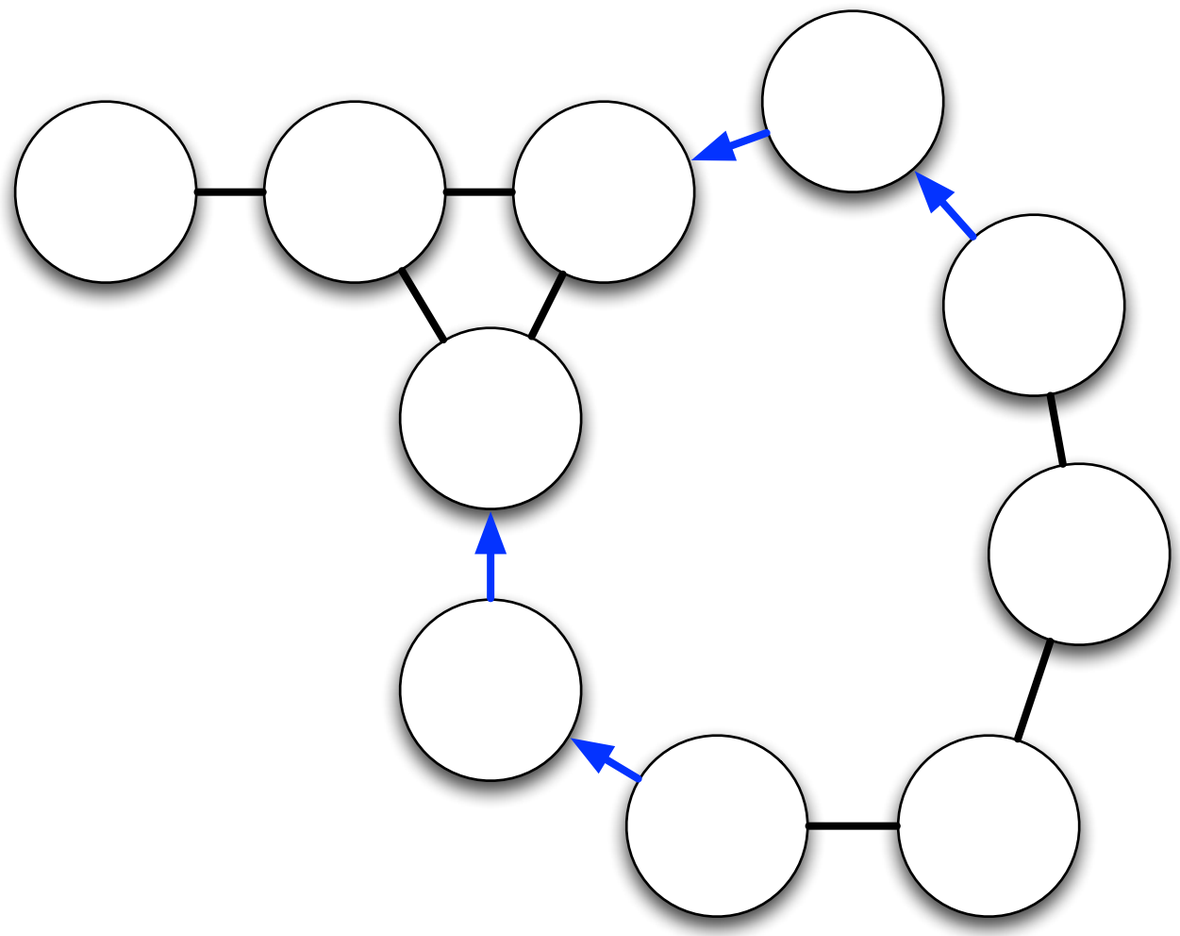
Stateless Flooding



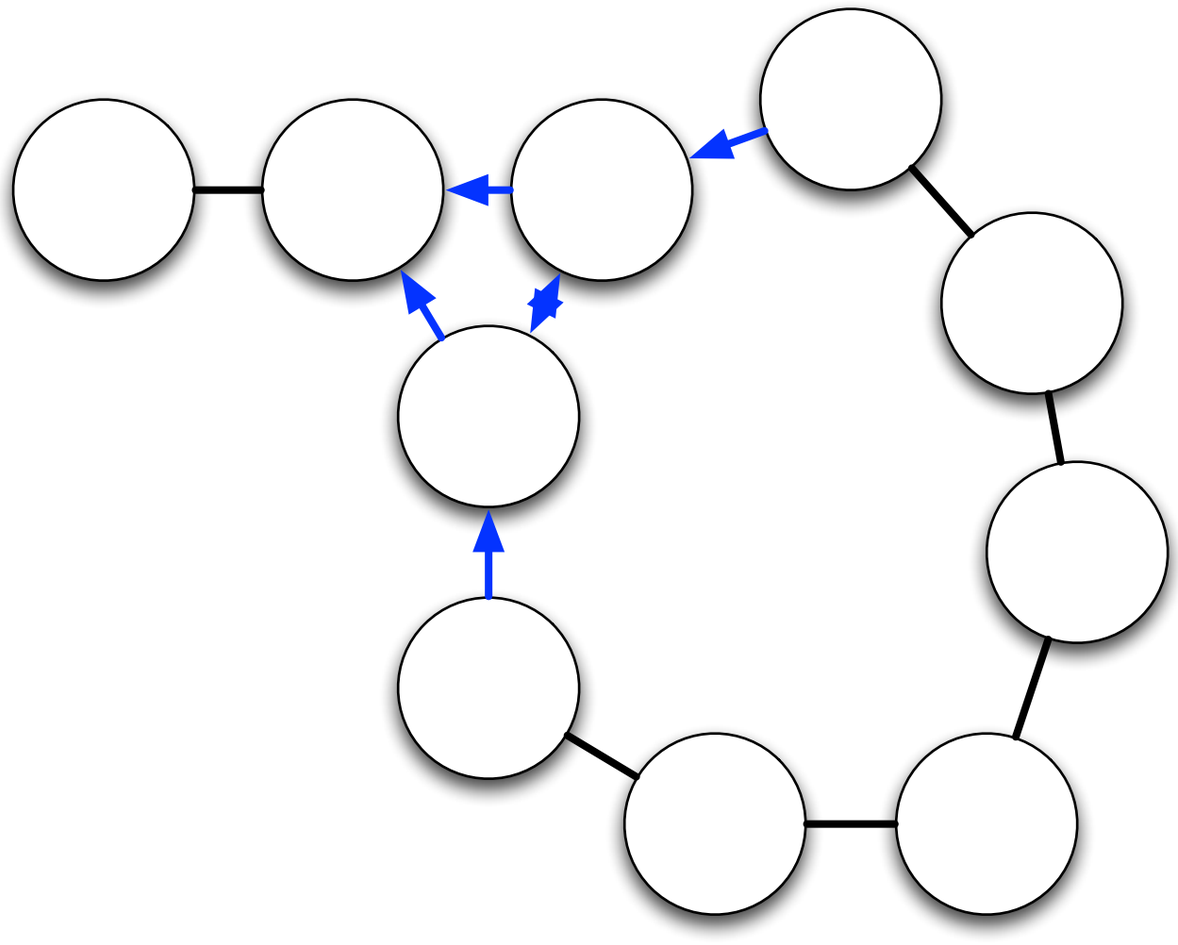
Stateless Flooding



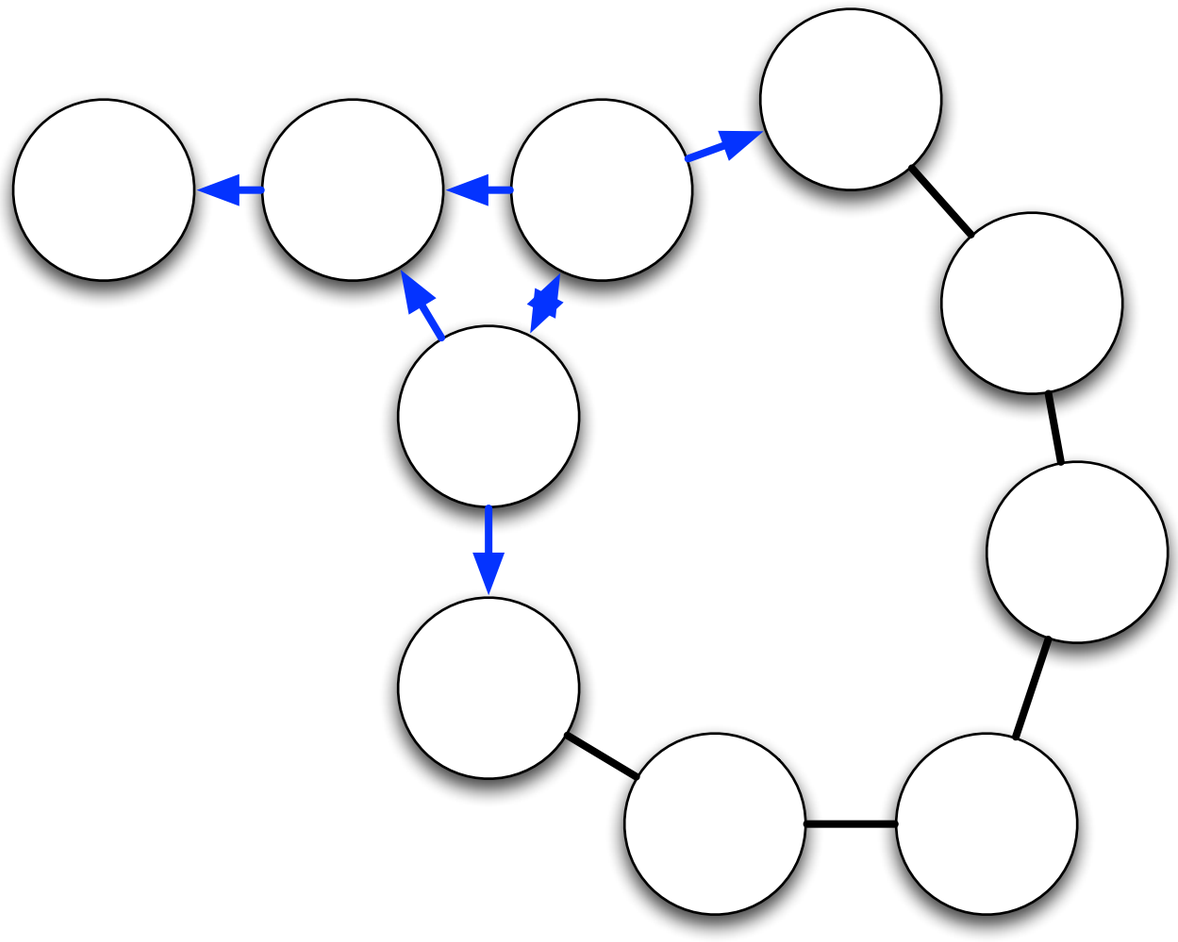
Stateless Flooding



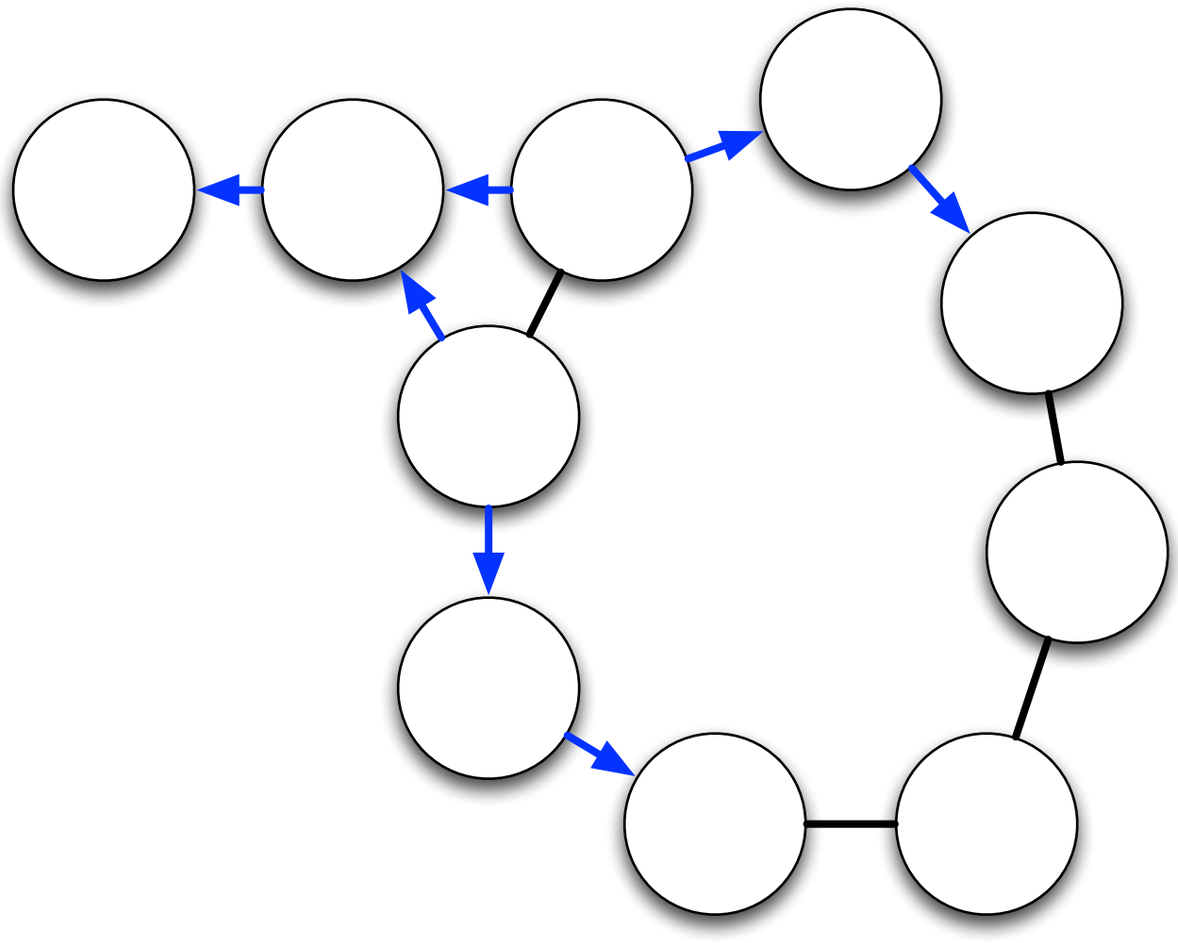
Stateless Flooding



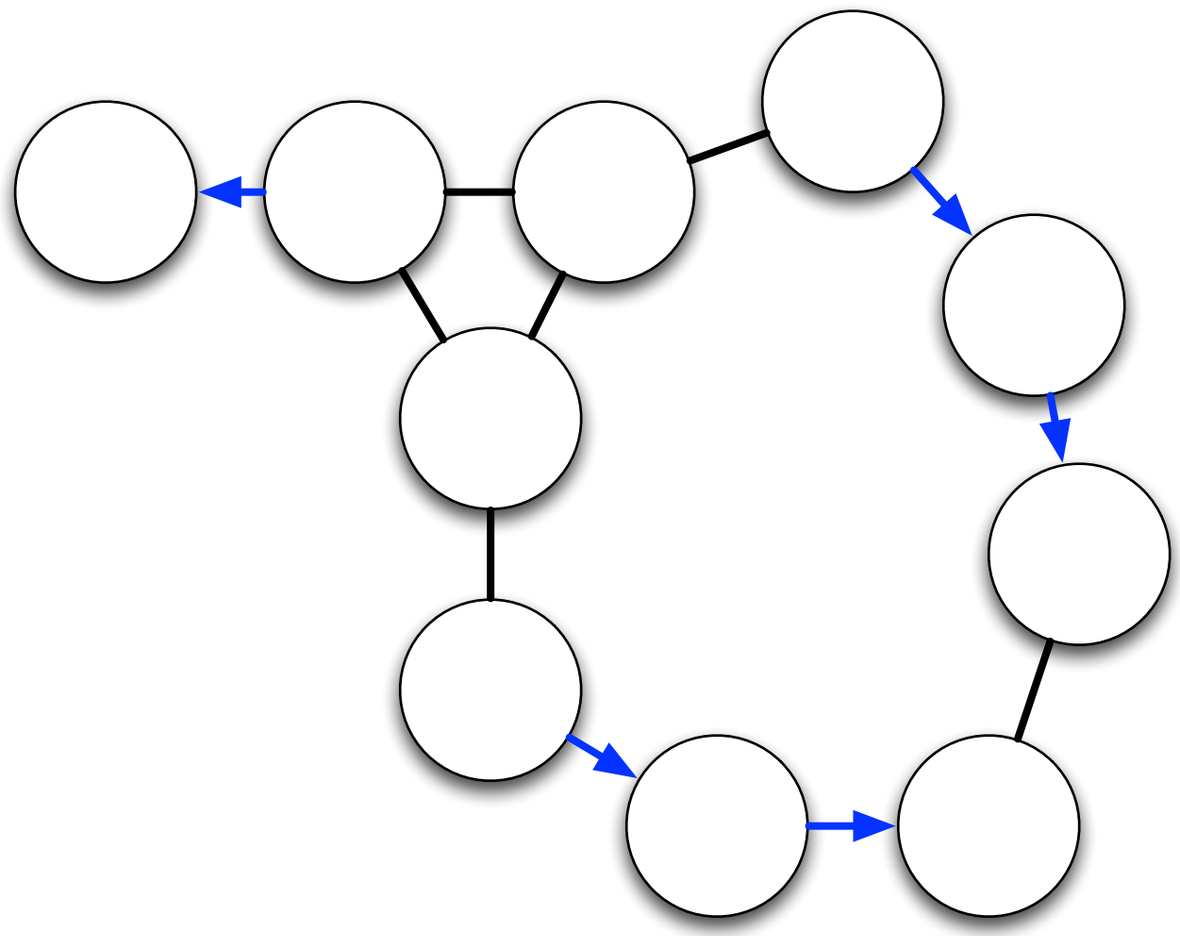
Stateless Flooding



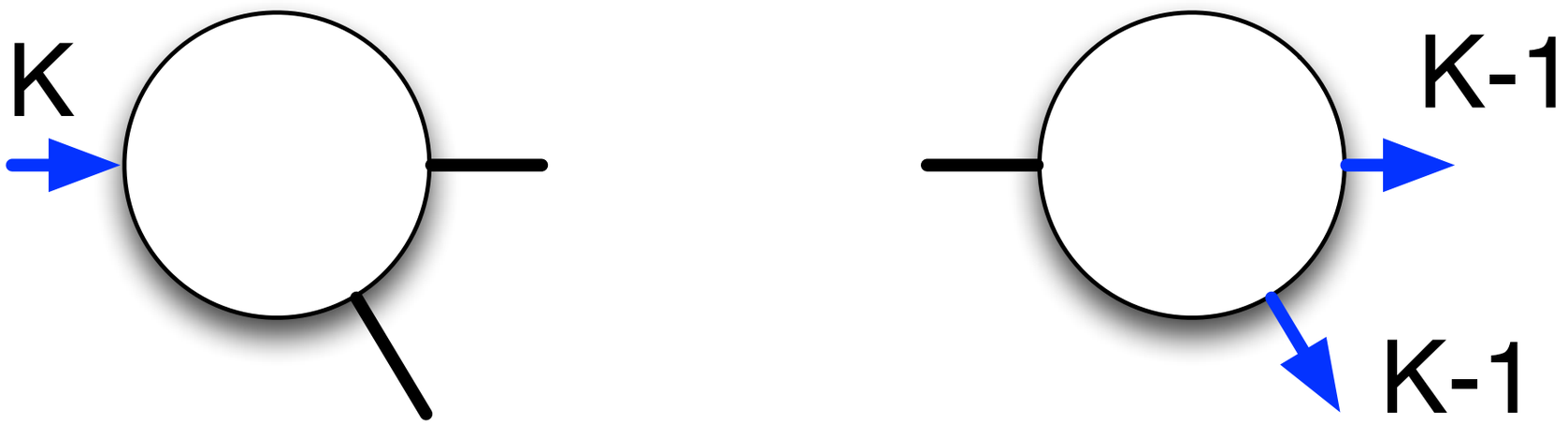
Stateless Flooding



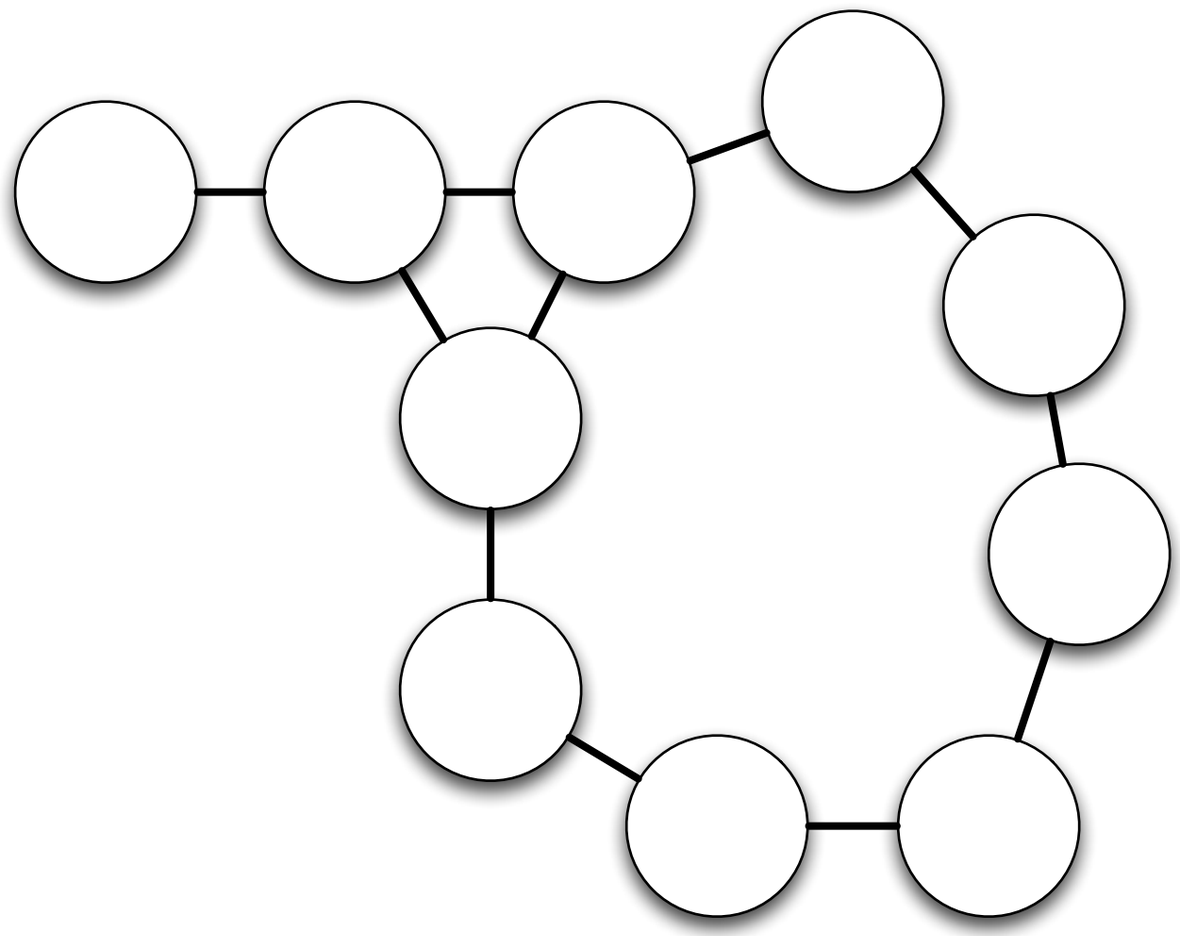
Stateless Flooding



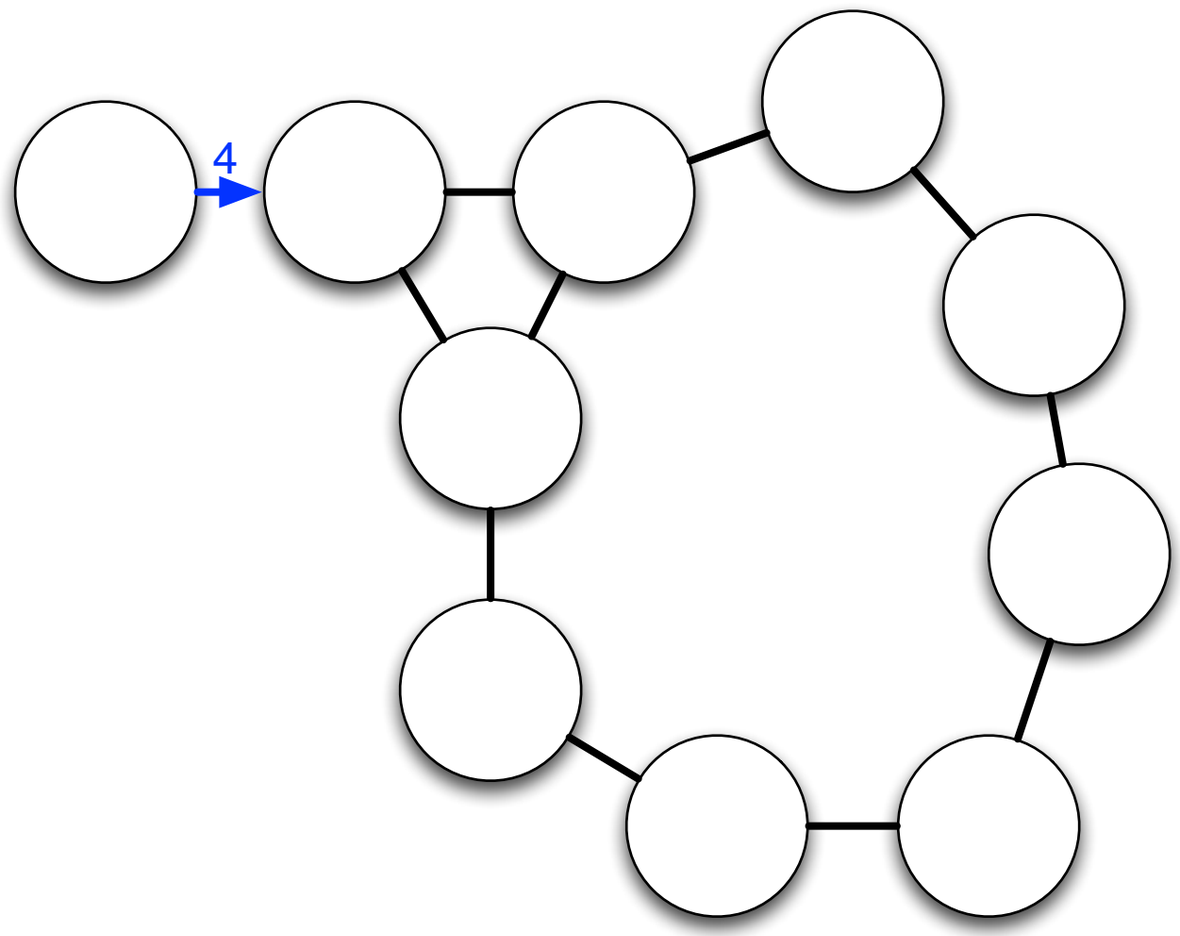
Flooding v2



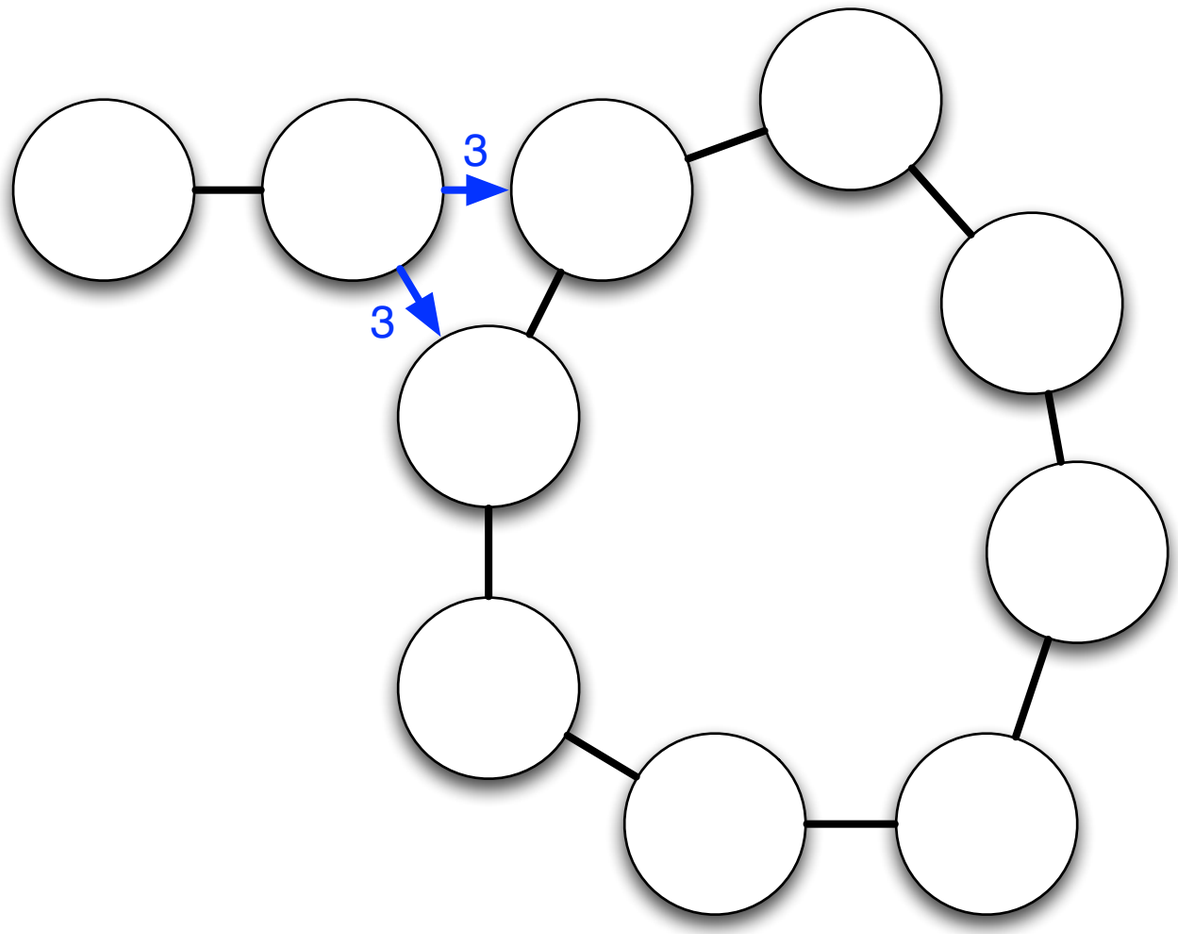
TTL Flooding



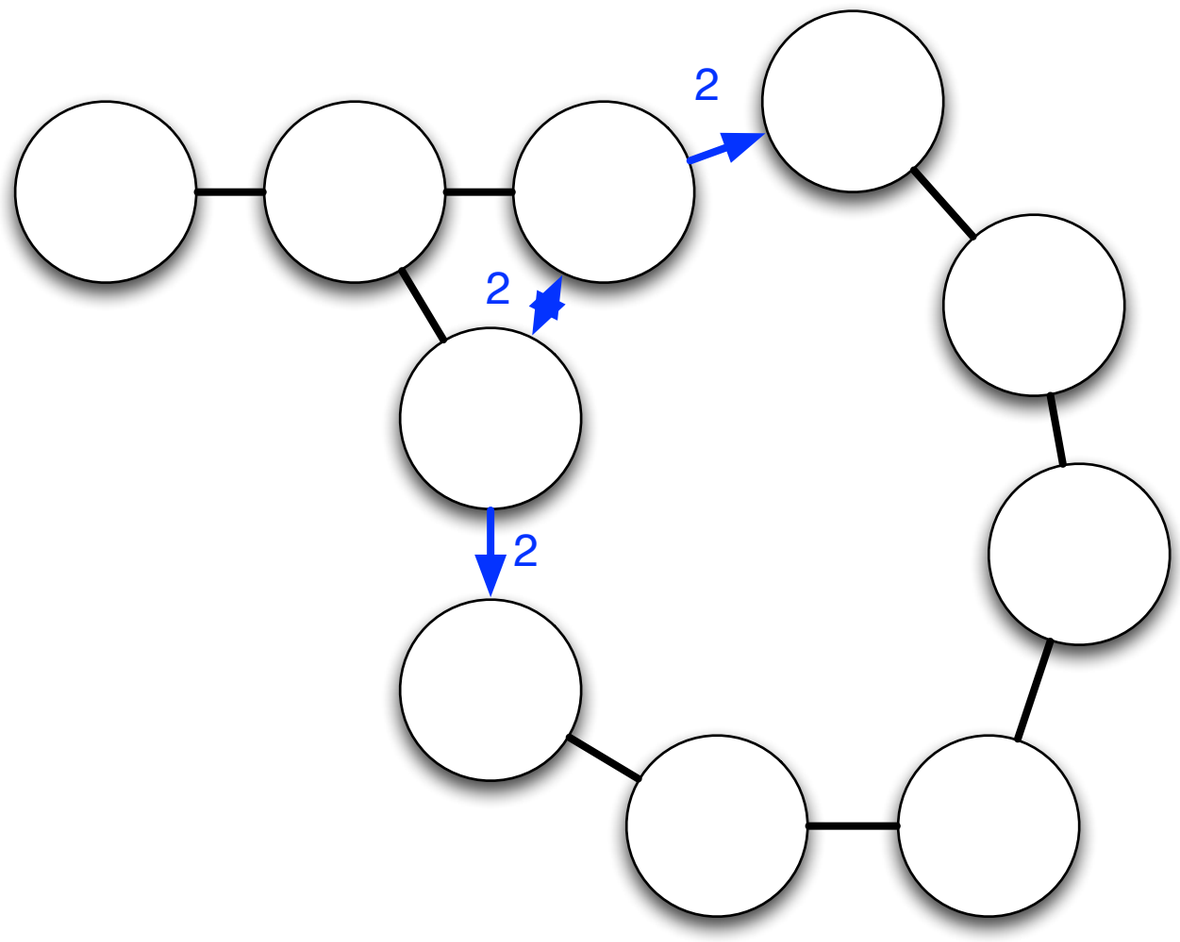
TTL Flooding



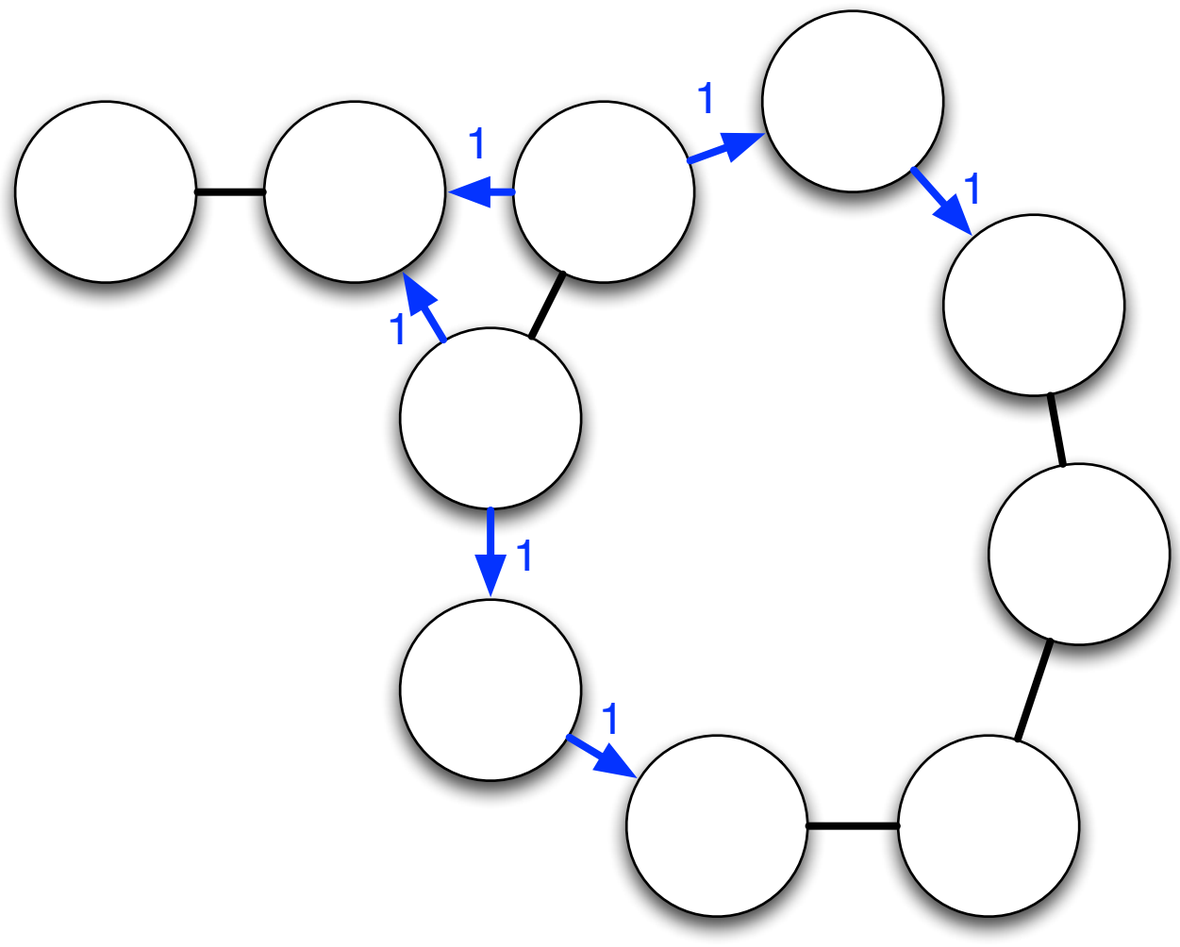
TTL Flooding



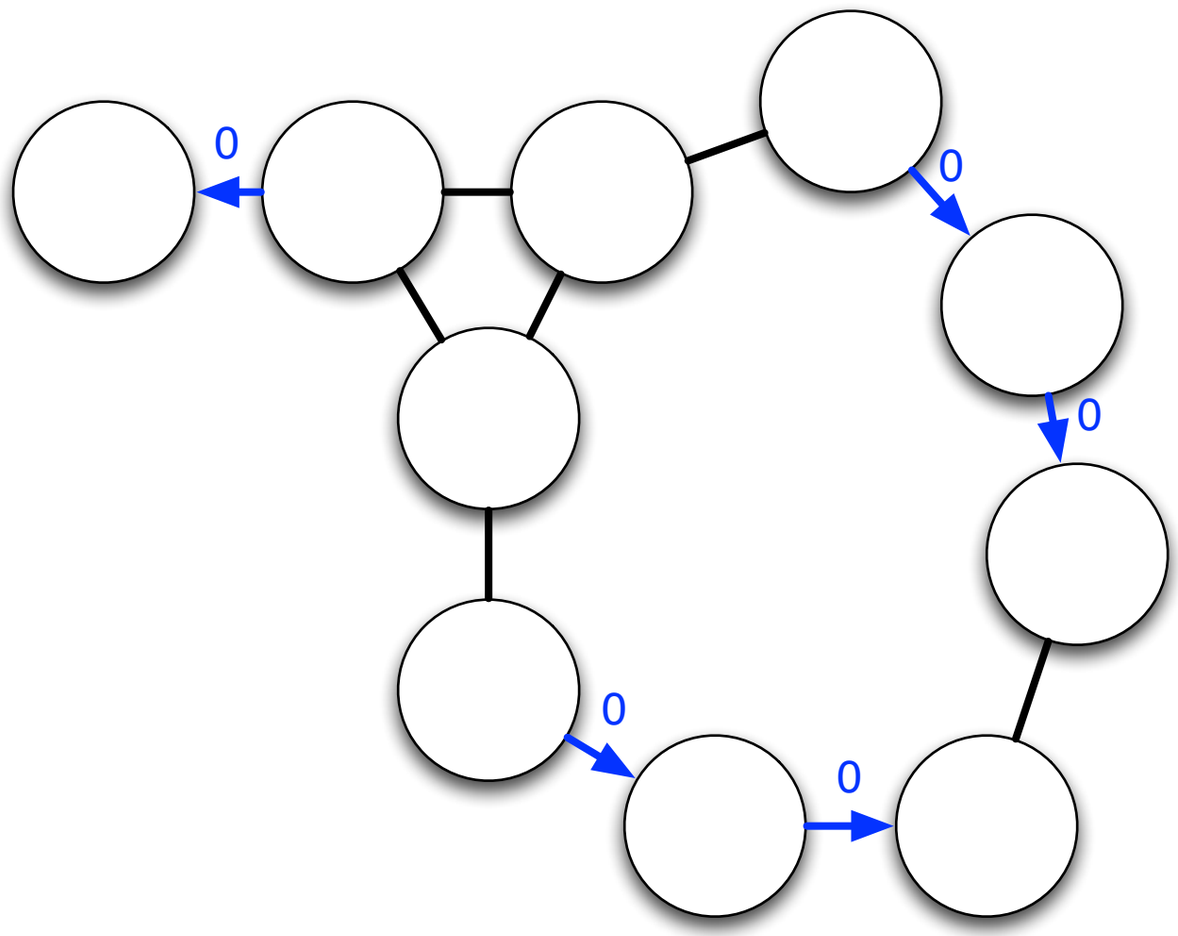
TTL Flooding



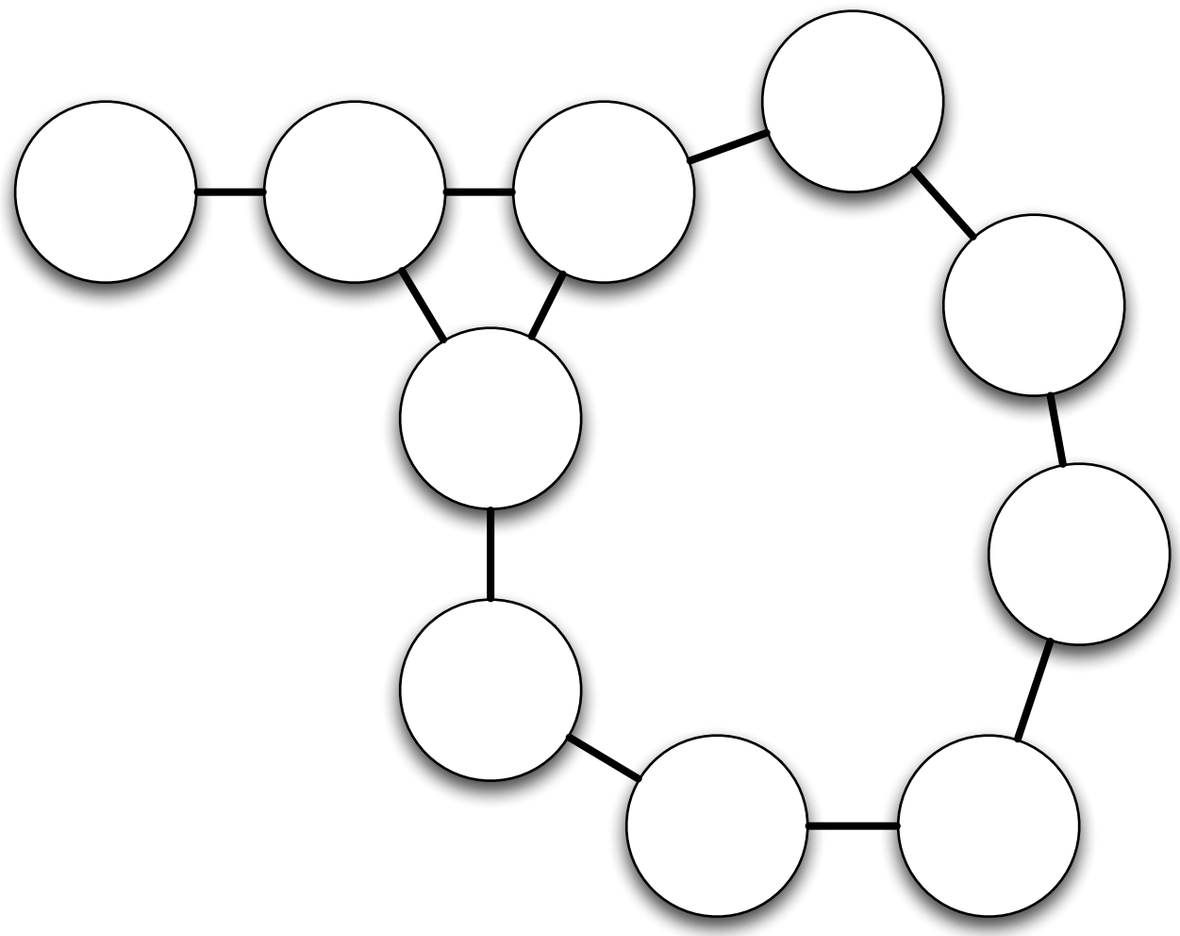
TTL Flooding



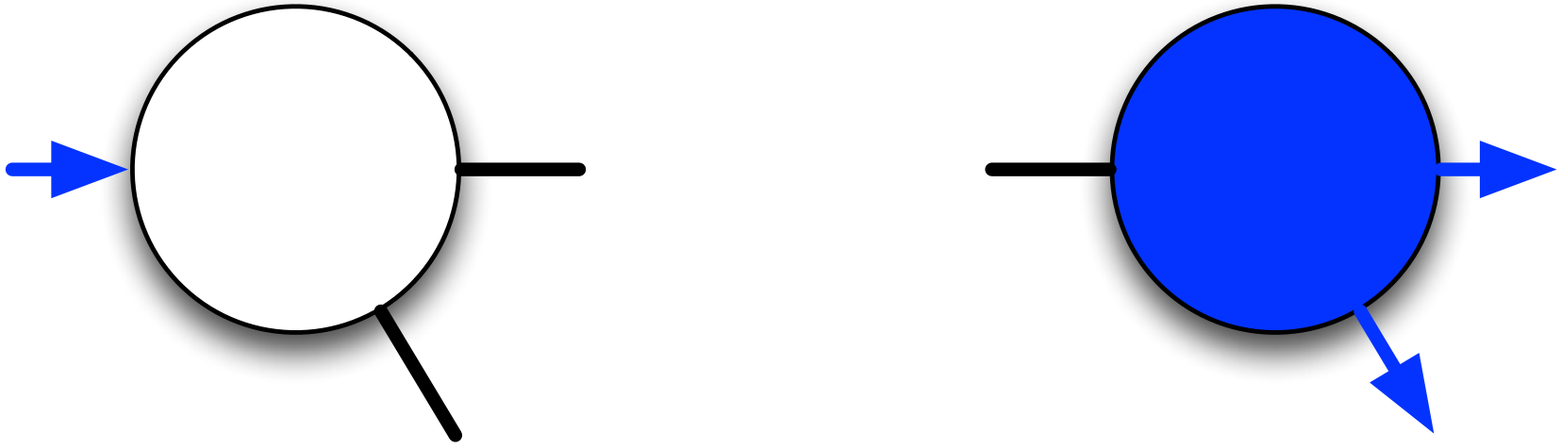
TTL Flooding



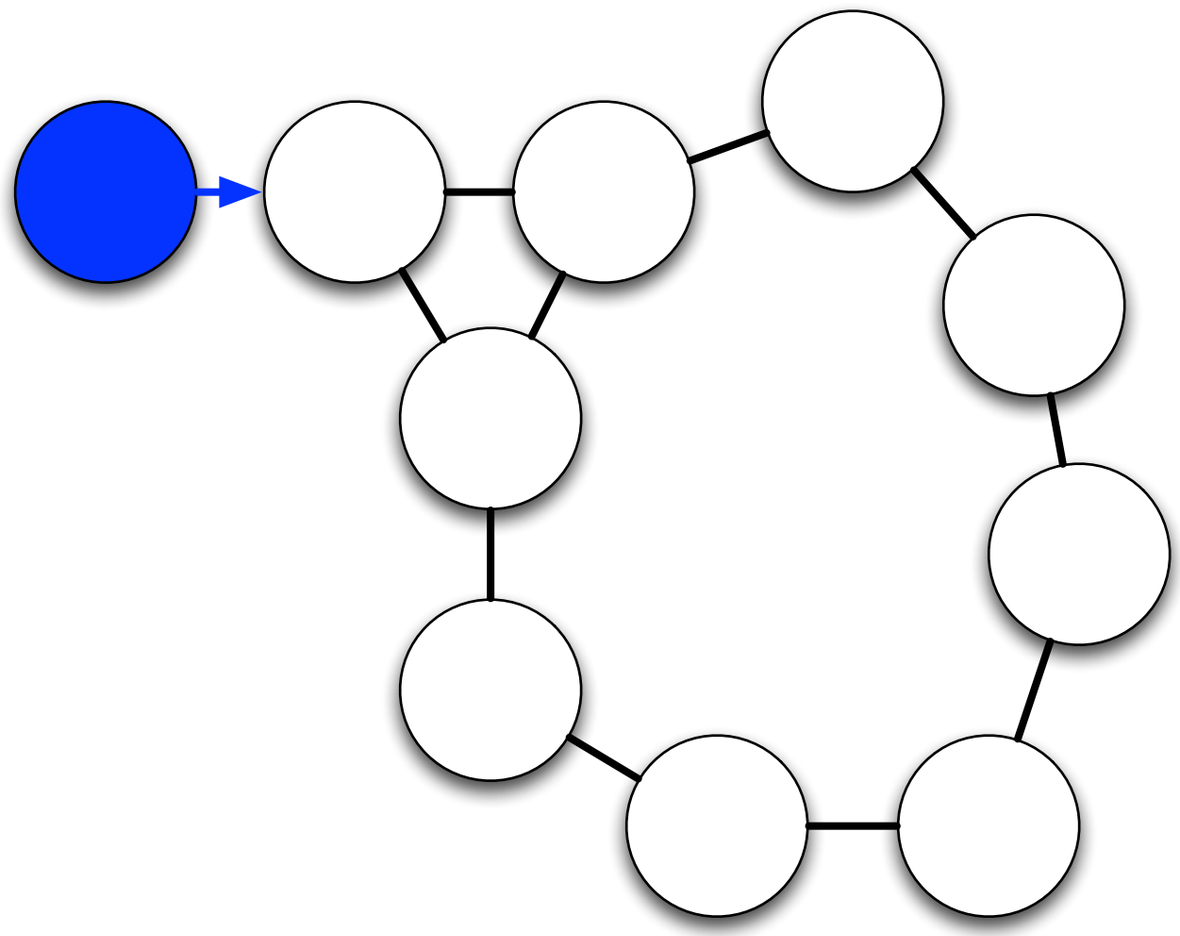
TTL Flooding



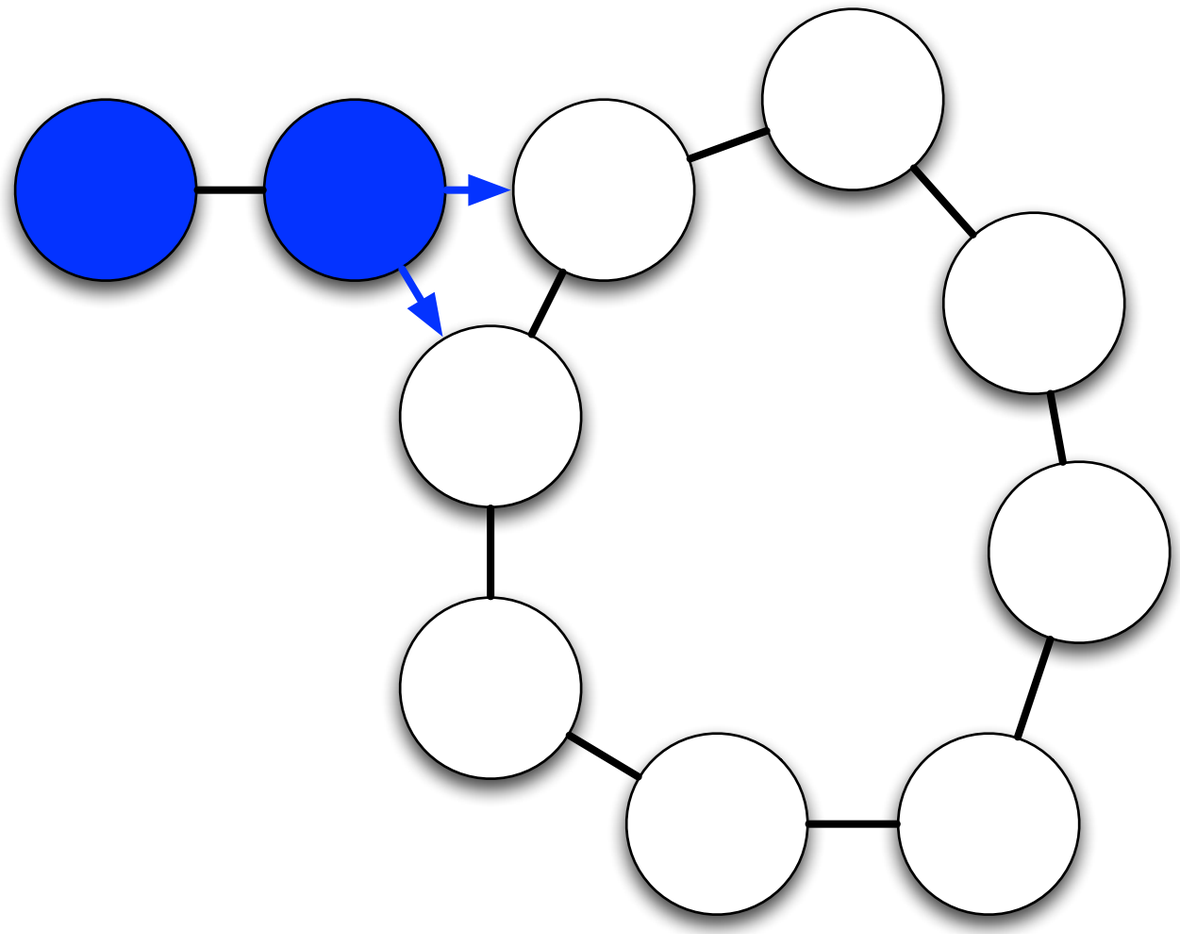
Flooding v3



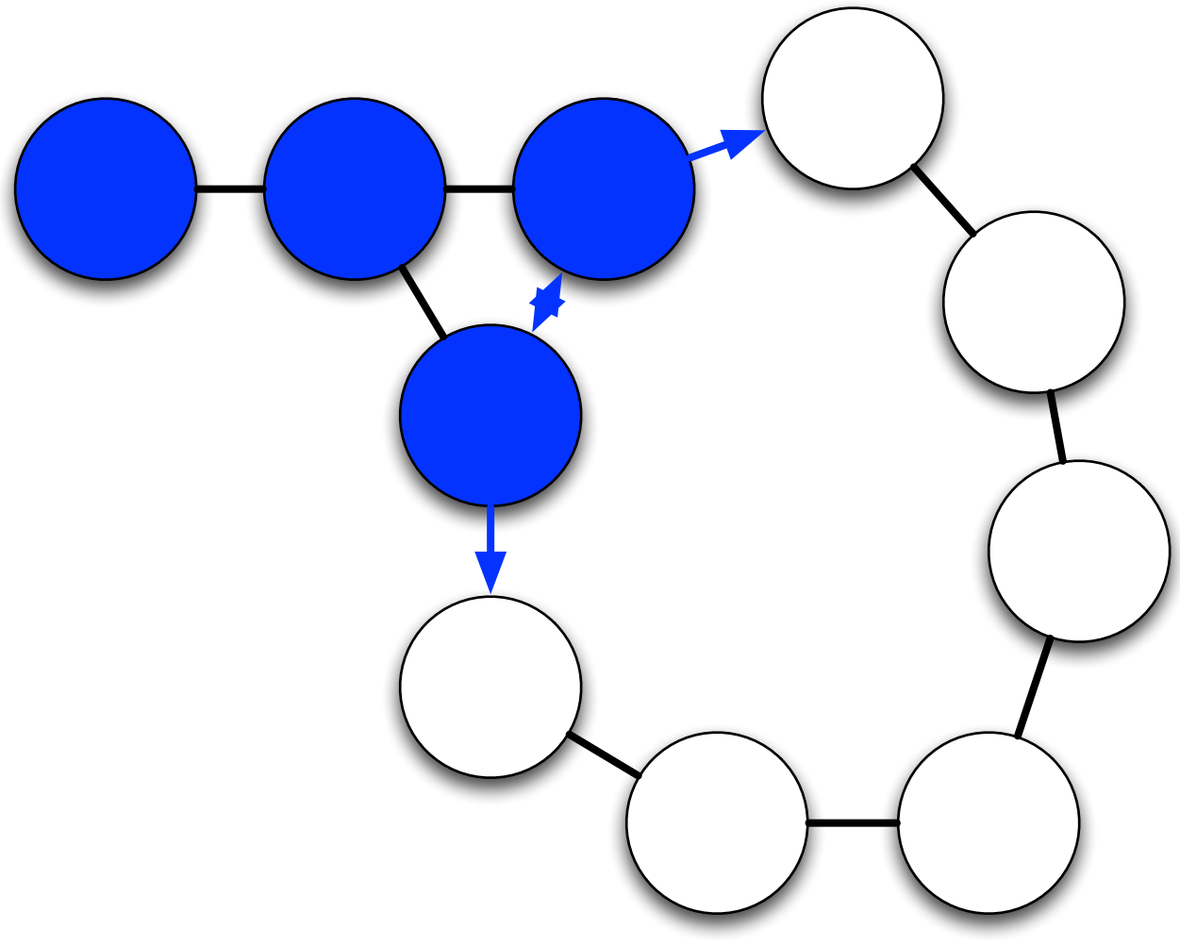
Stateful Flooding



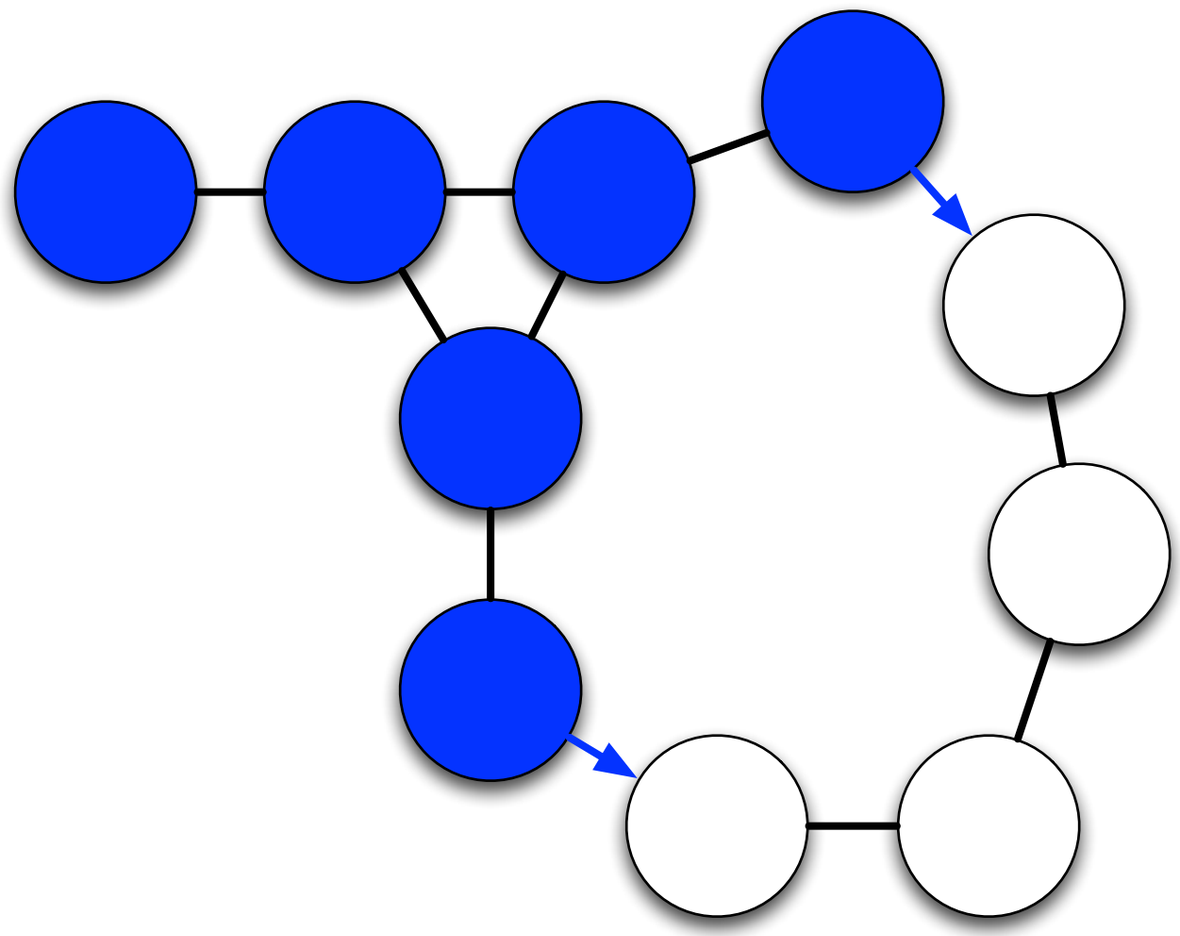
Stateful Flooding



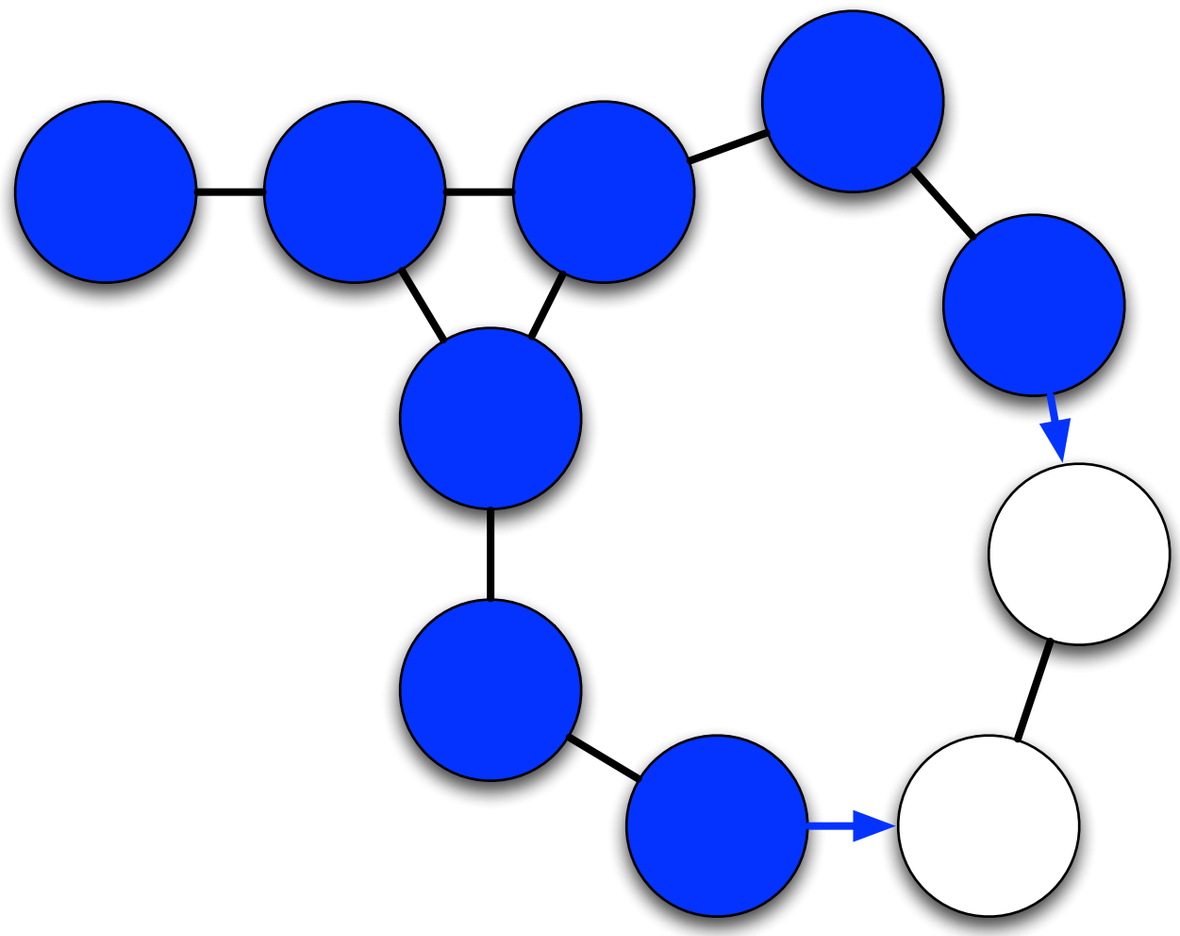
Stateful Flooding



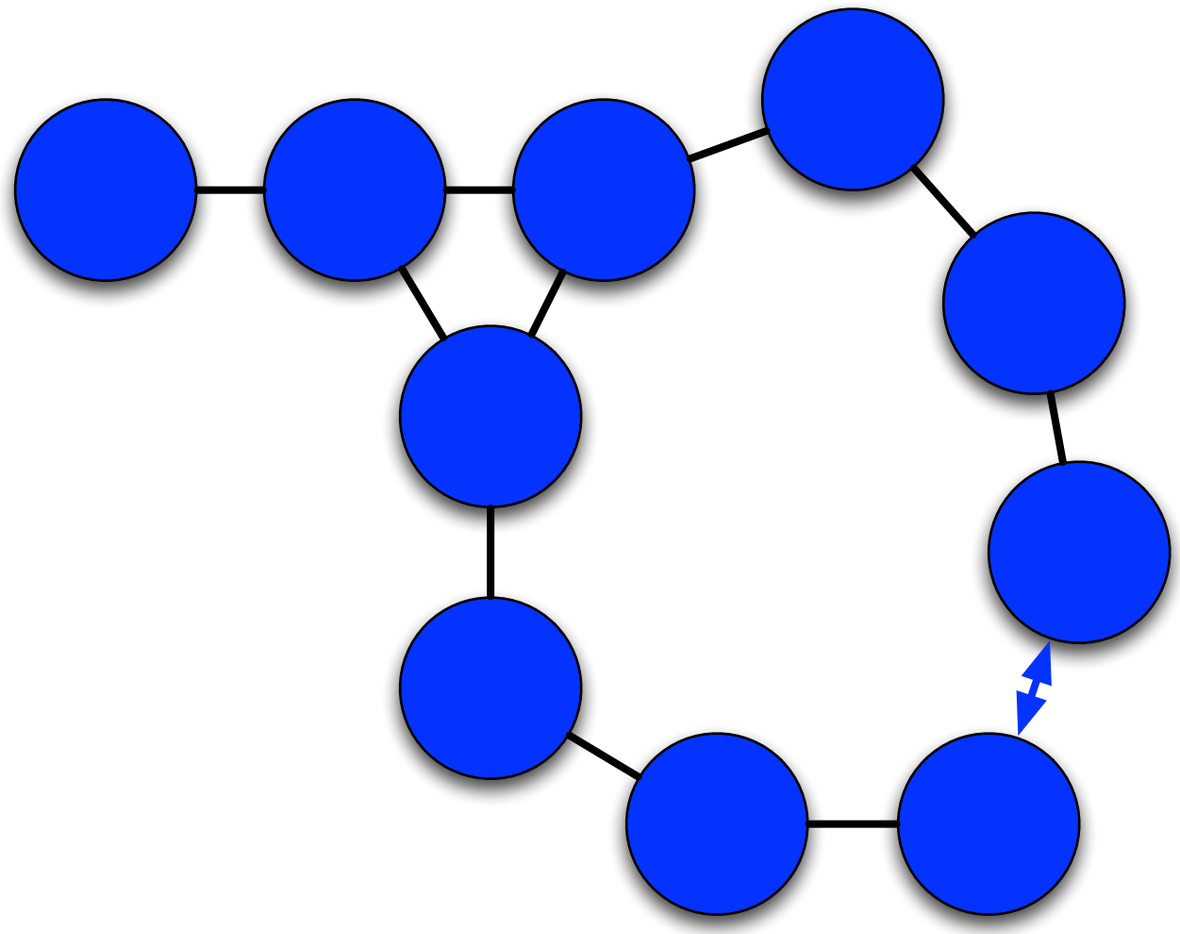
Stateful Flooding



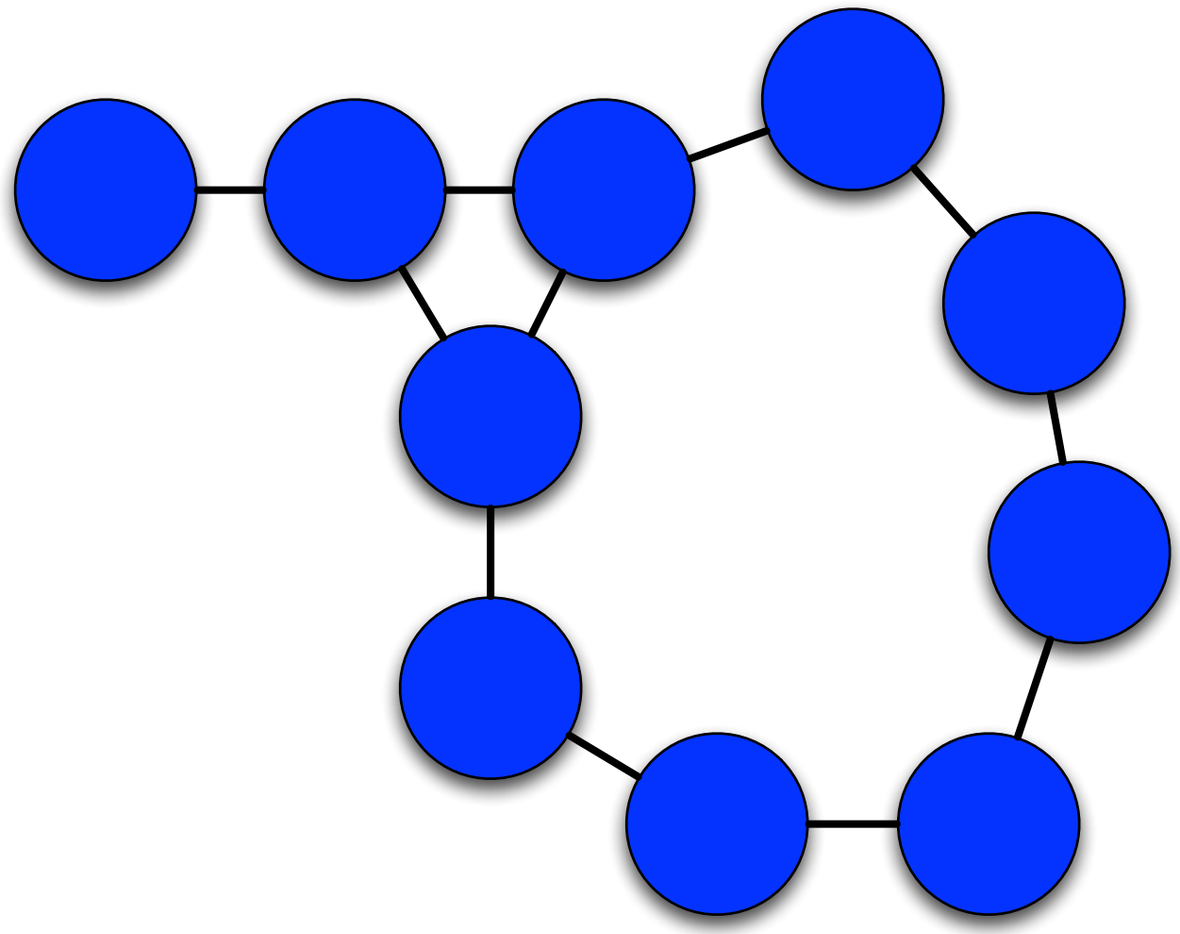
Stateful Flooding



Stateful Flooding



Stateful Flooding

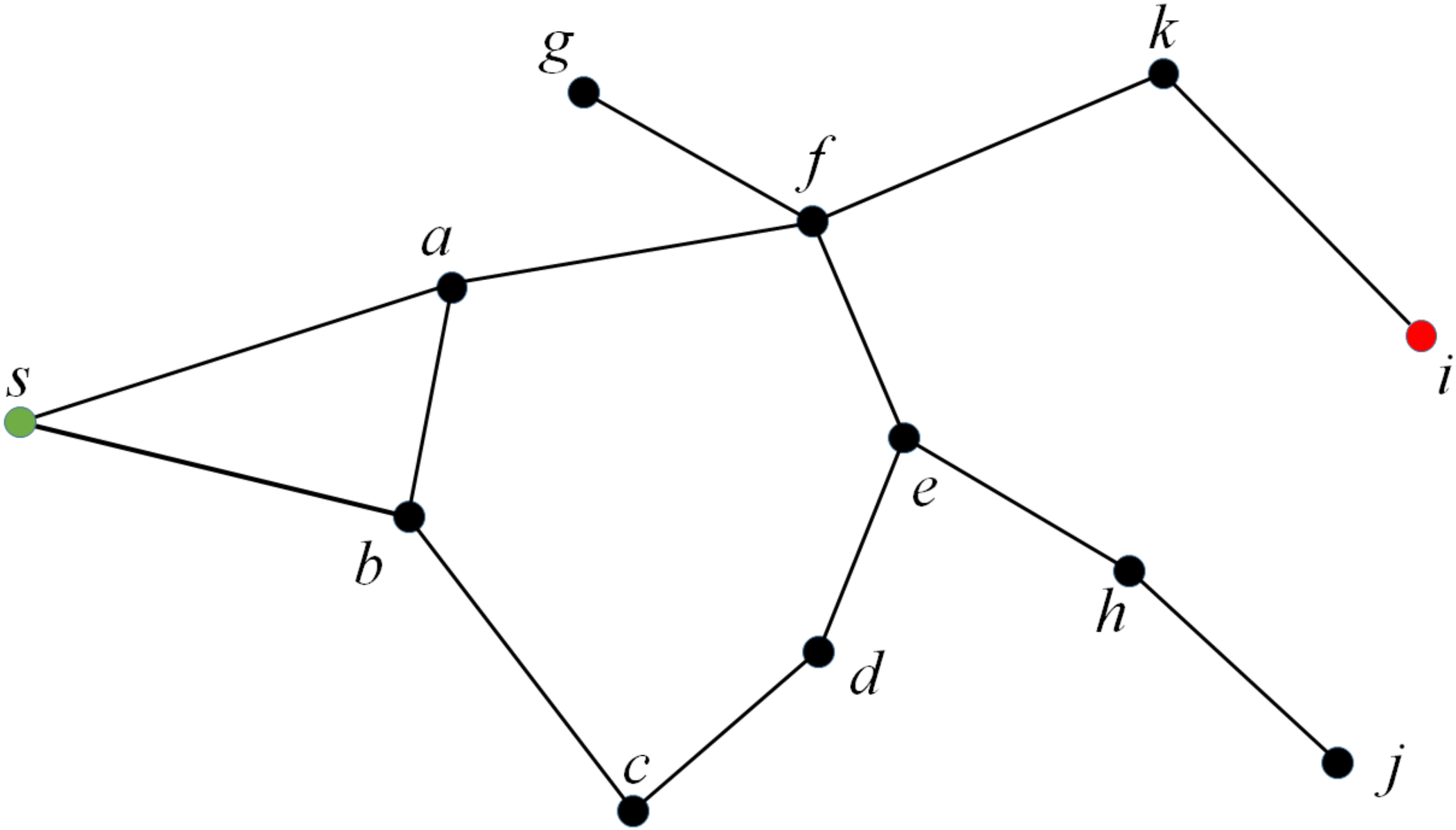


Geometric Routing

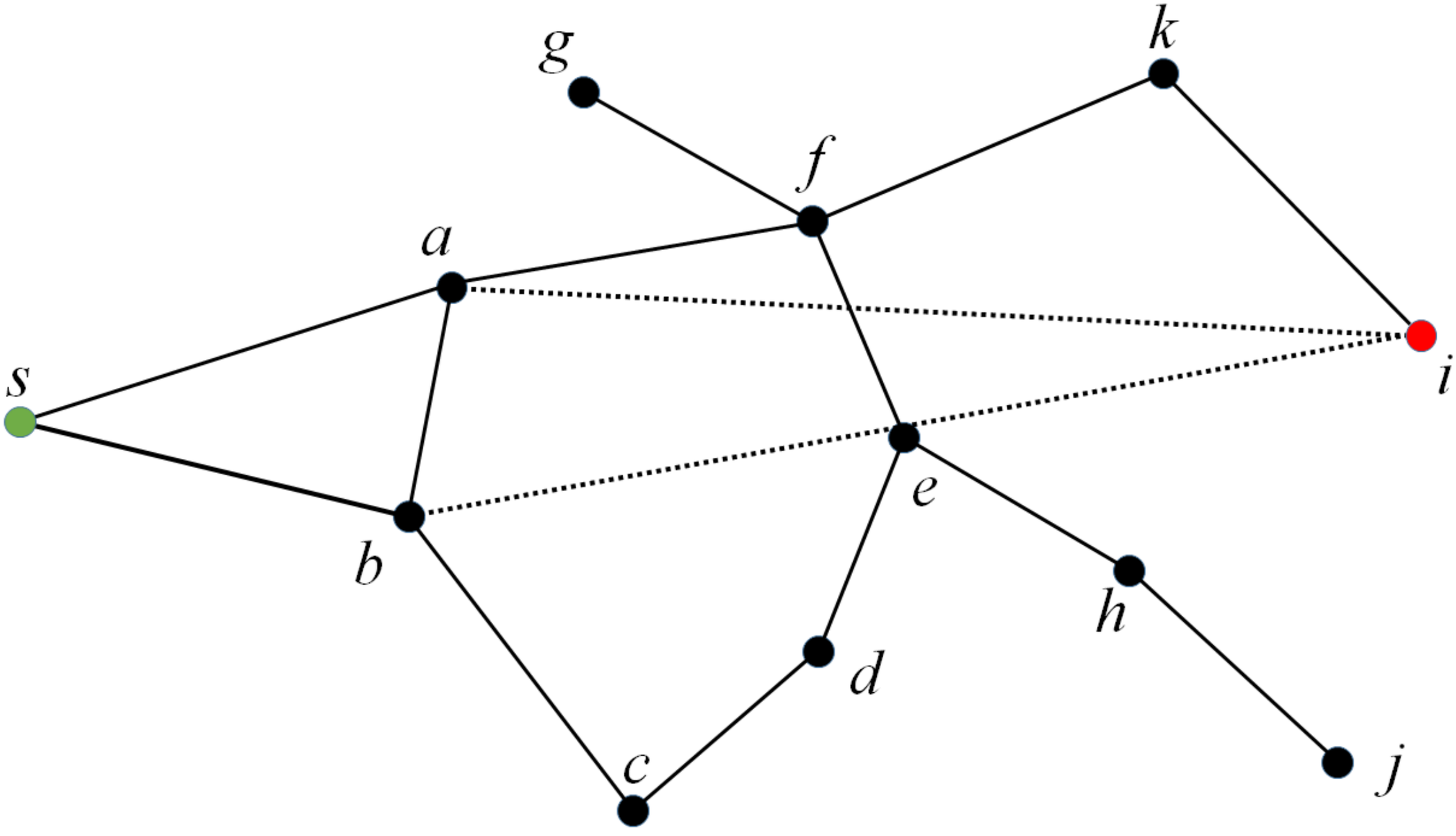
- Each node is aware of its *coordinates* (and those of its neighbors)
    - The message contains the coordinates of the destination
    - **Goal**: deliver the message to the destination *without routing tables*

Stojmenovic, Ivan (2002). "Position based routing in ad hoc networks". IEEE Communications Magazine. 40 (7): 128–134.

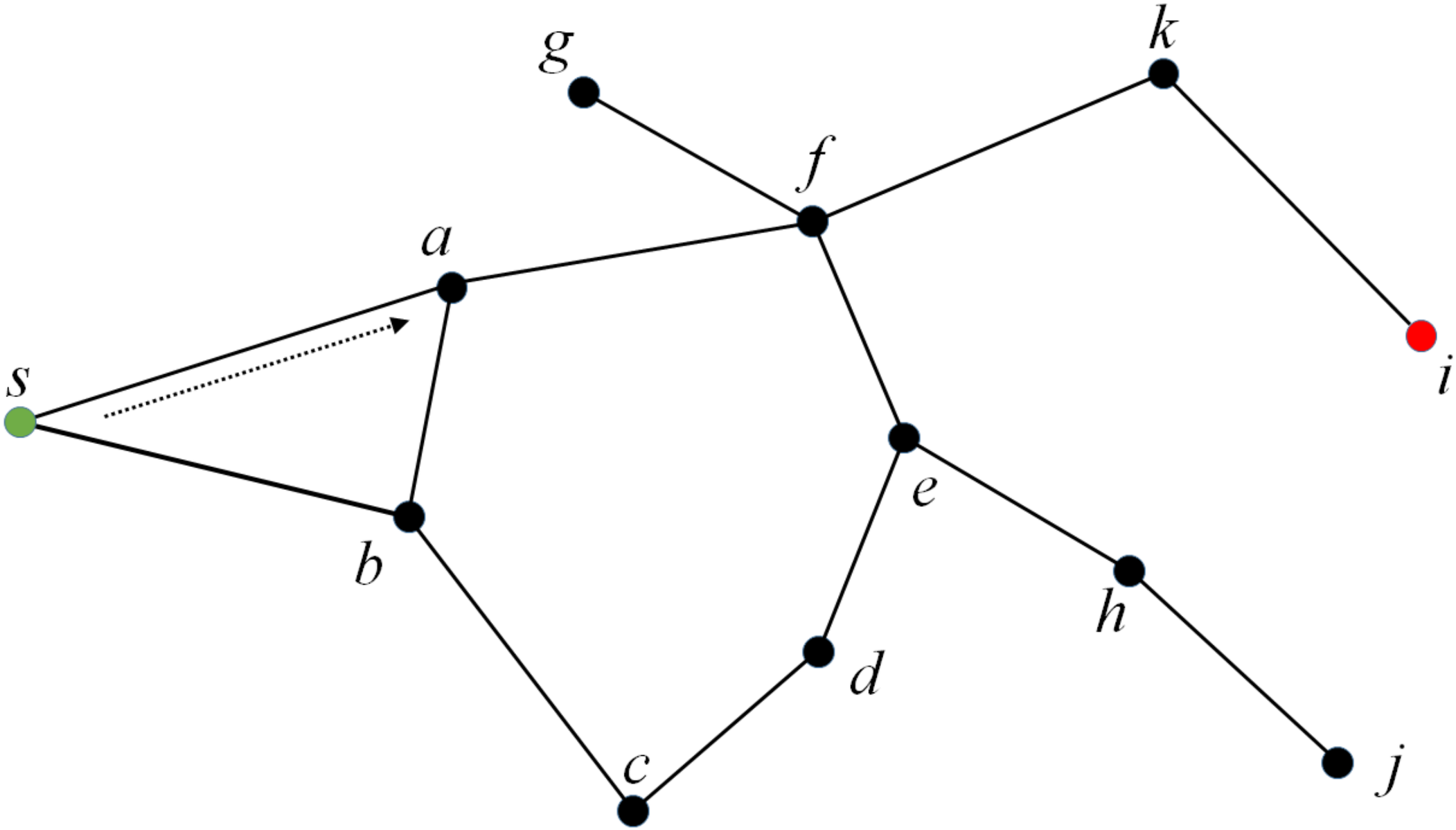
Greedy Routing



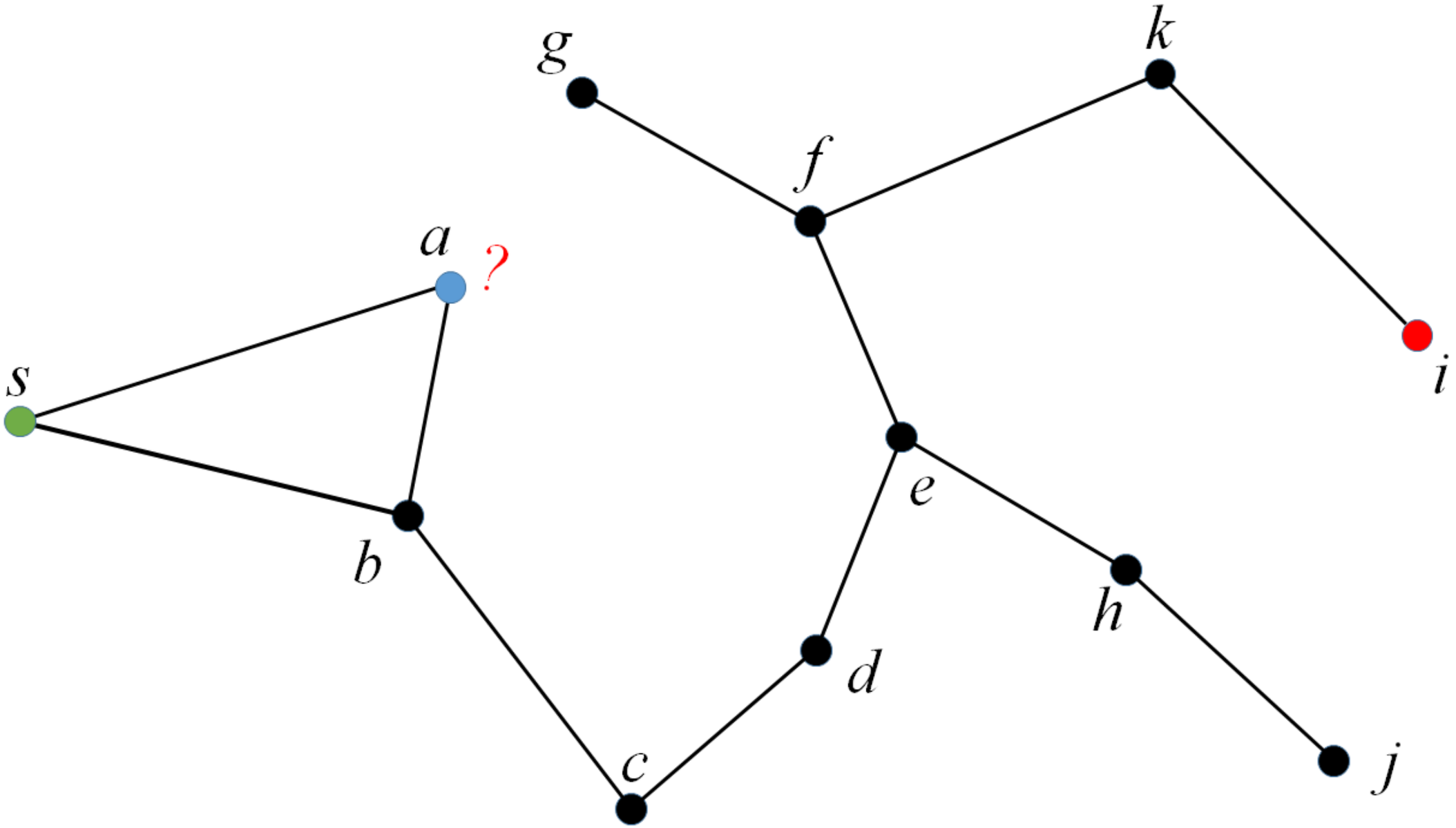
Greedy Routing



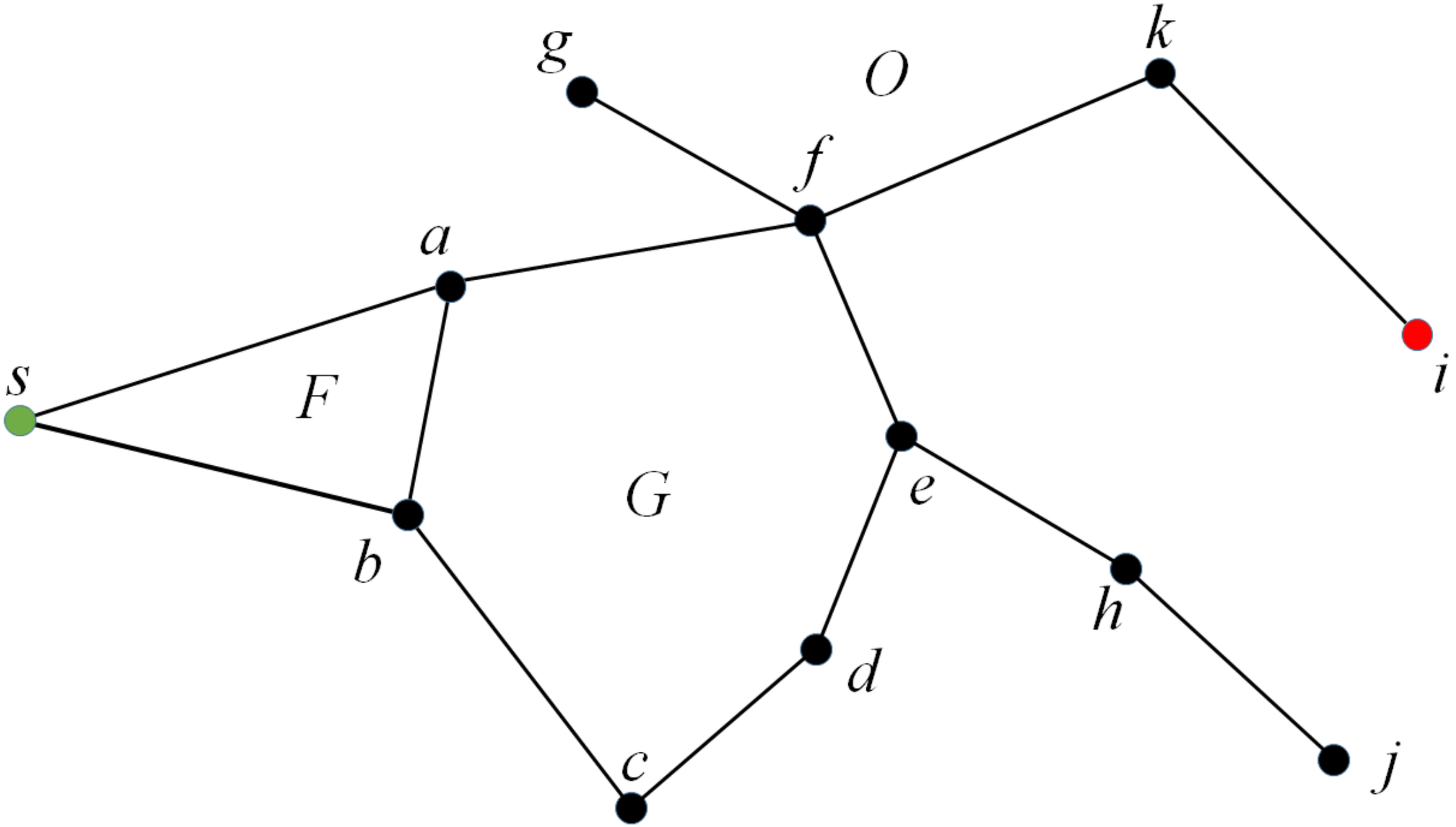
Greedy Routing



Greedy Routing

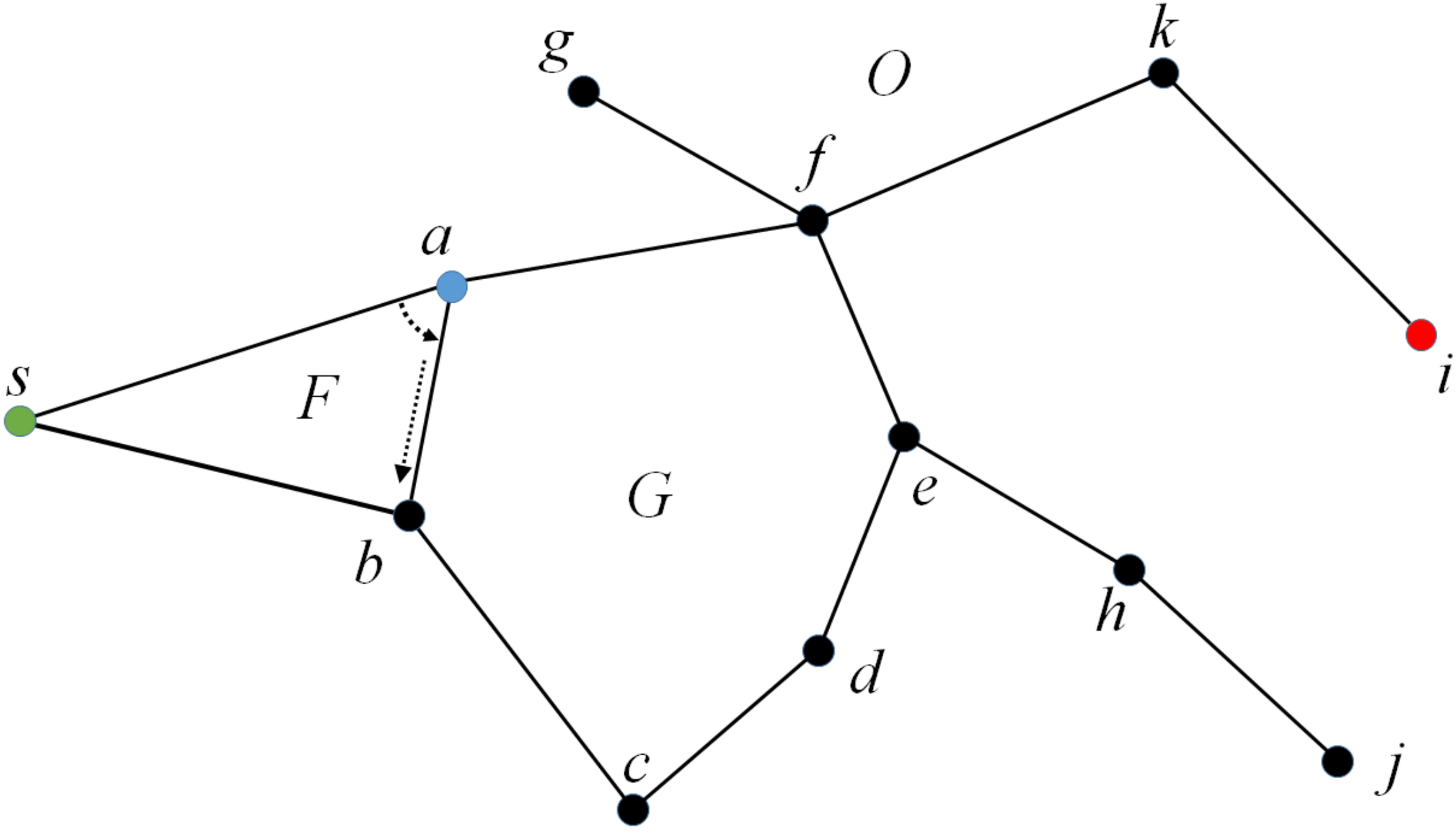


Face Routing

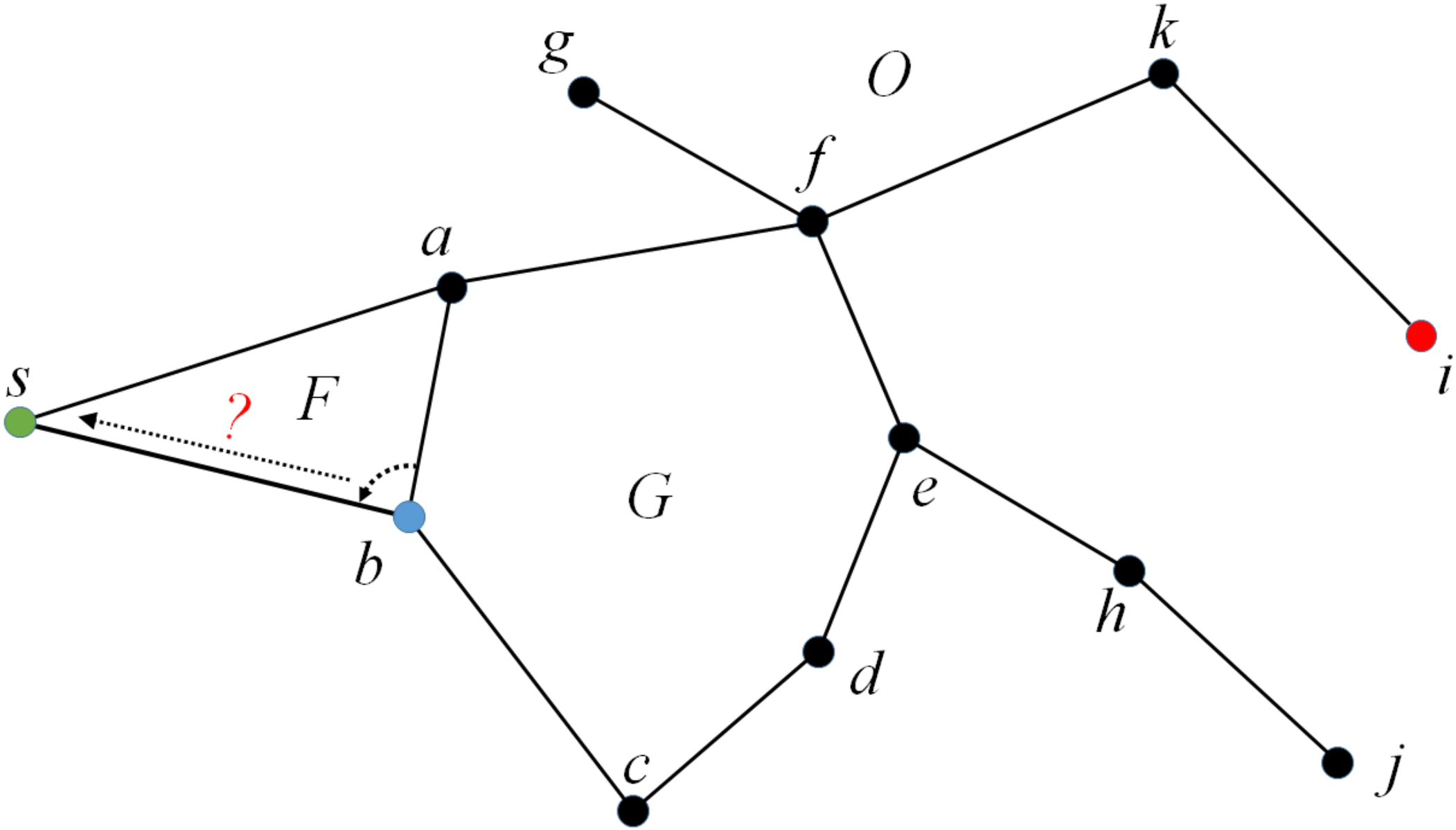


Bose, P.; Morin, P.; Stojmenovic, I.; Urrutia, J. (1999). "Routing with guaranteed delivery in ad hoc wireless networks". Proc. of the 3rd international workshop on discrete algorithms and methods for mobile computing and communications (DIALM '99). pp. 48–55.

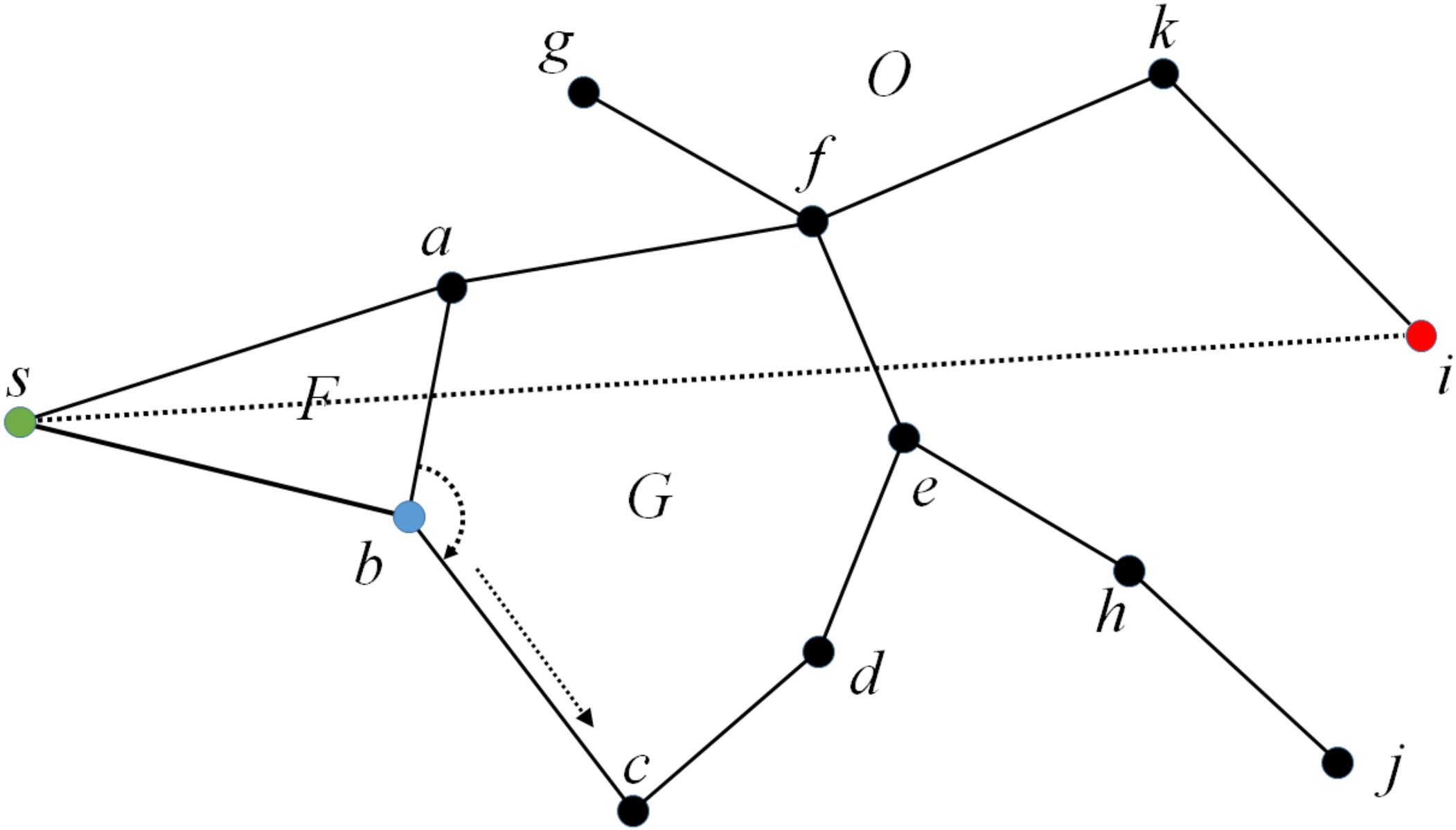
Face Routing



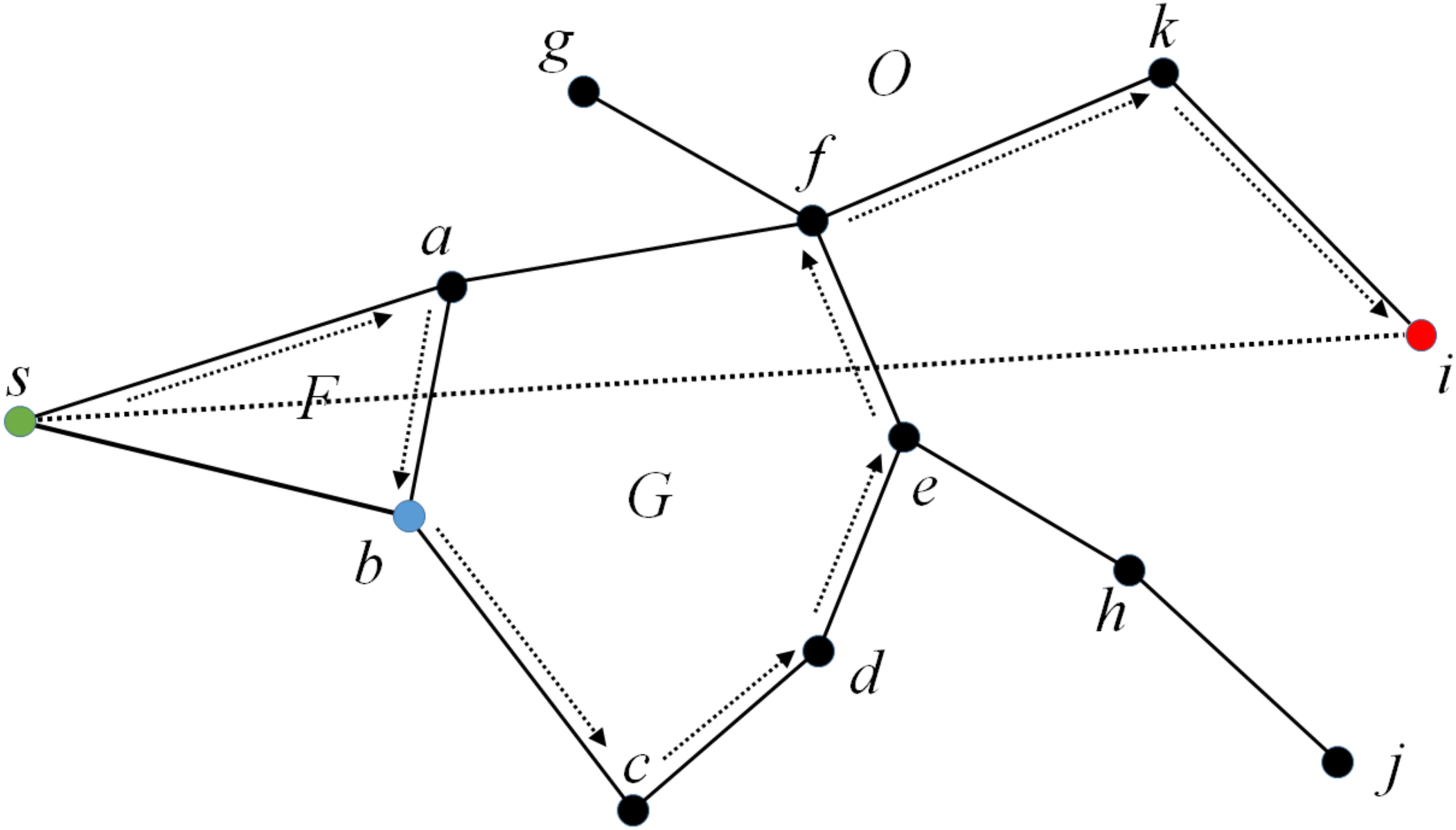
Face Routing



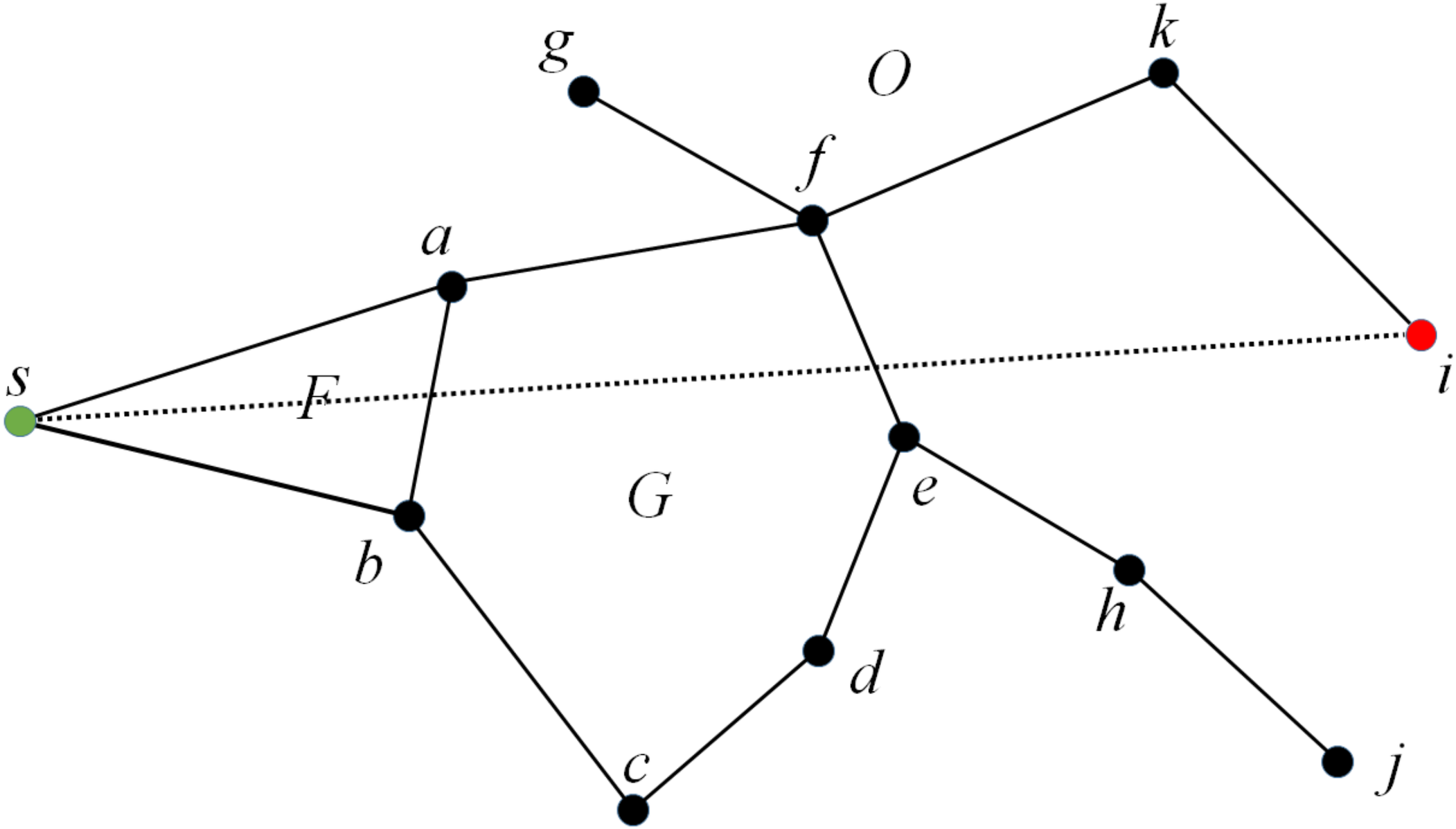
Face Routing



Face Routing

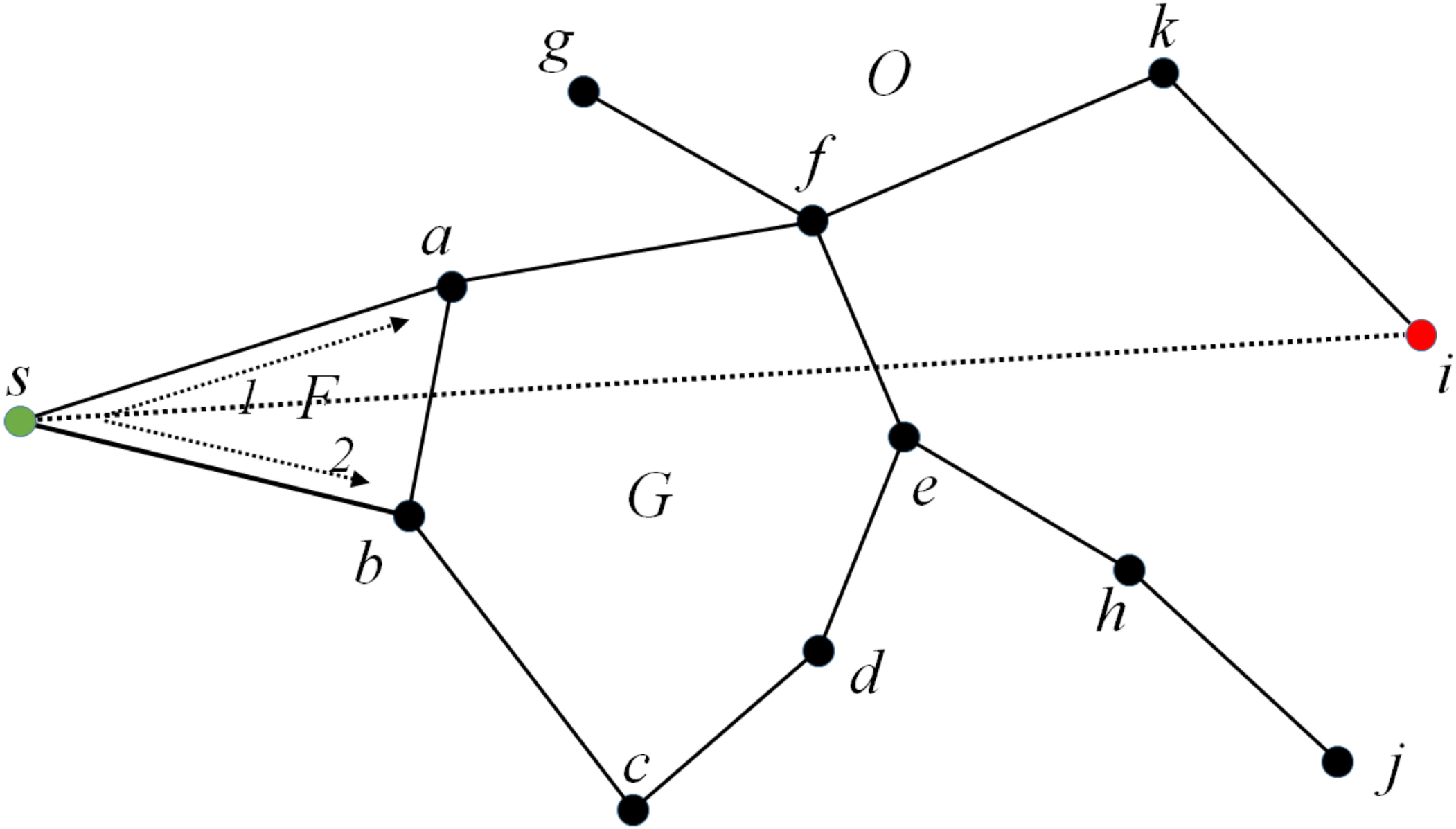


Concurrent Face Routing

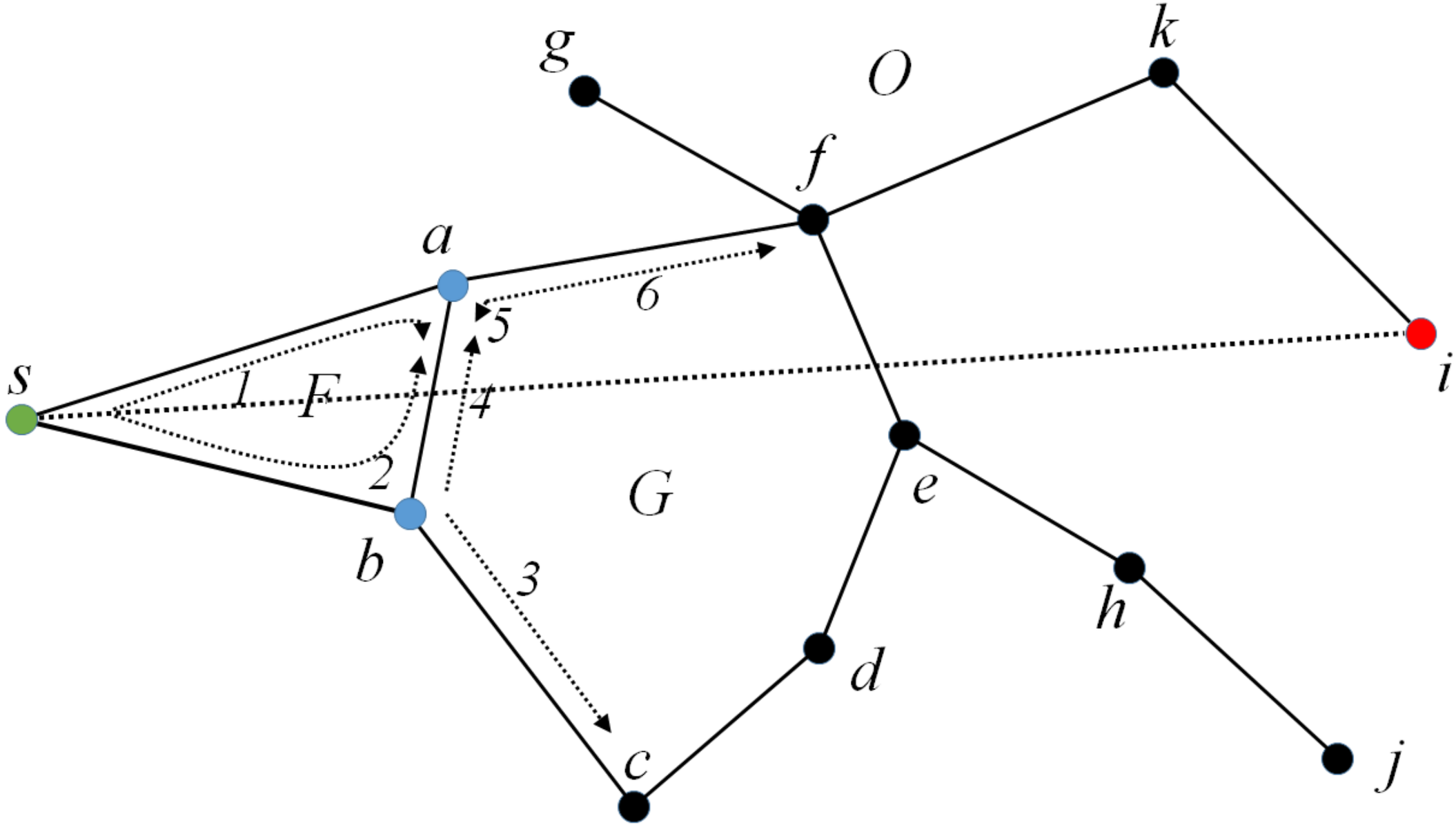


Thomas Clouser, Mark Miyashita, Mikhail Nesterenko: Concurrent face traversal for efficient geometric routing. J. Parallel Distrib. Comput. 72(5): 627-636 (2012)

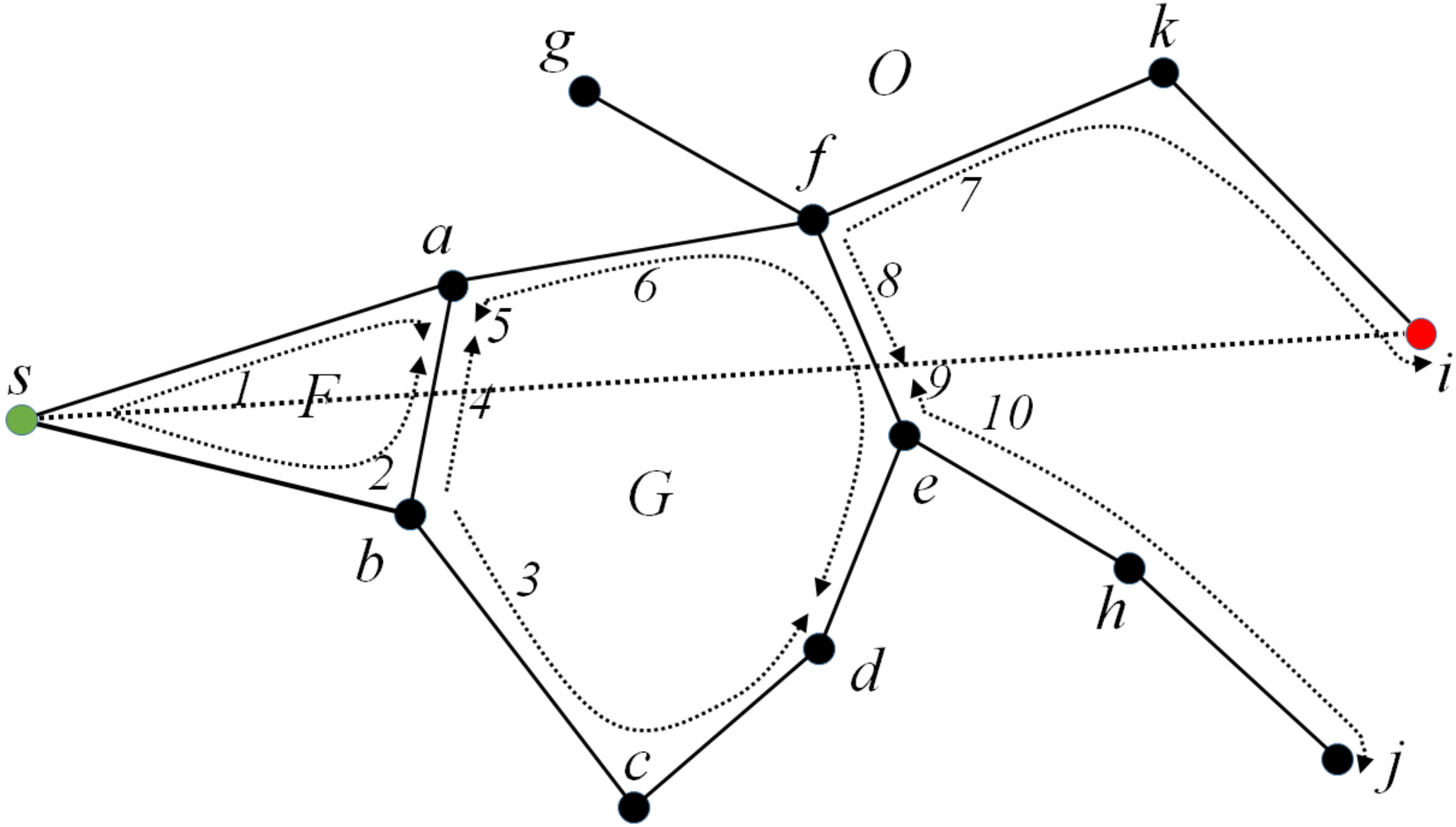
Concurrent Face Routing



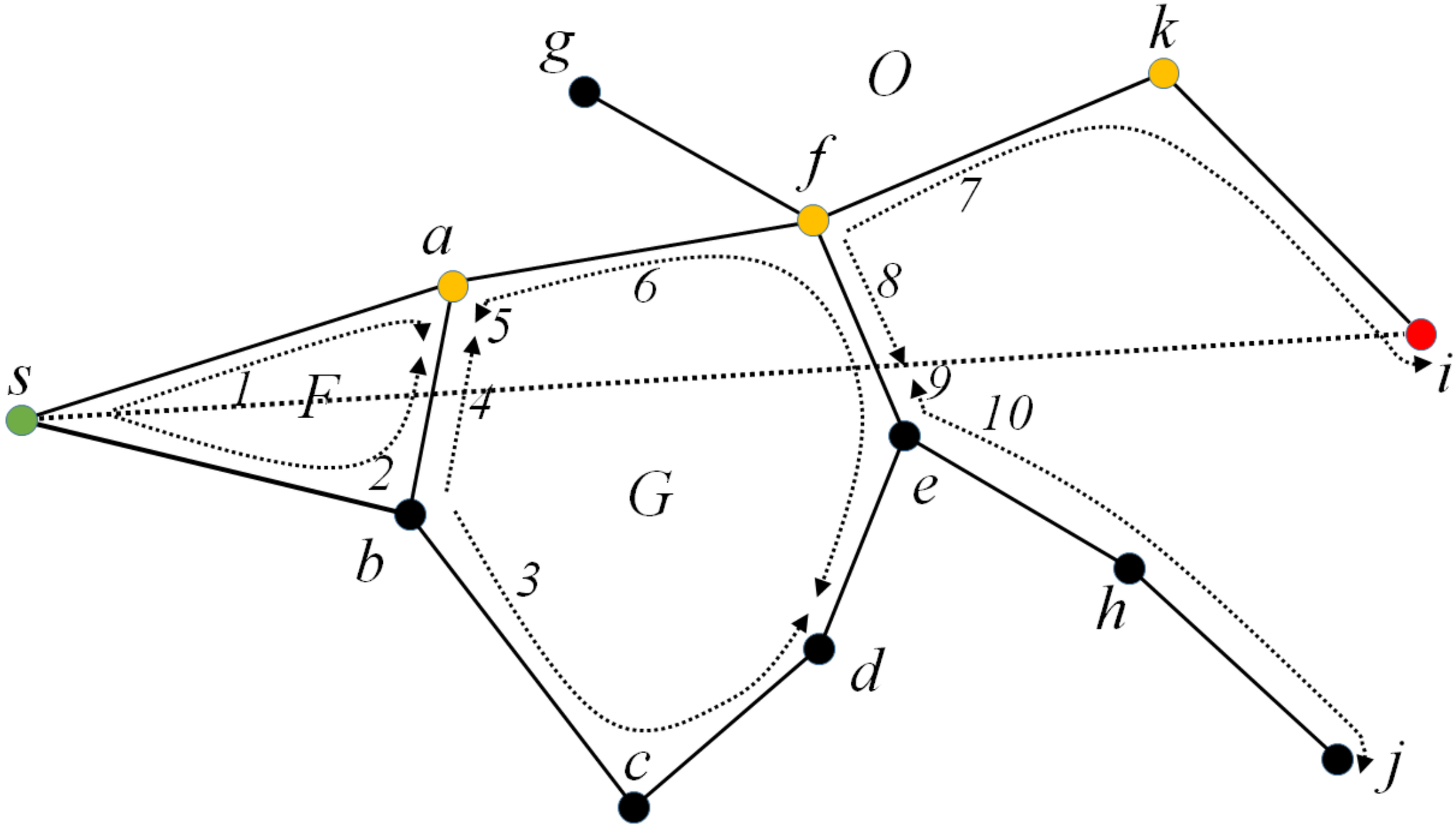
Concurrent Face Routing



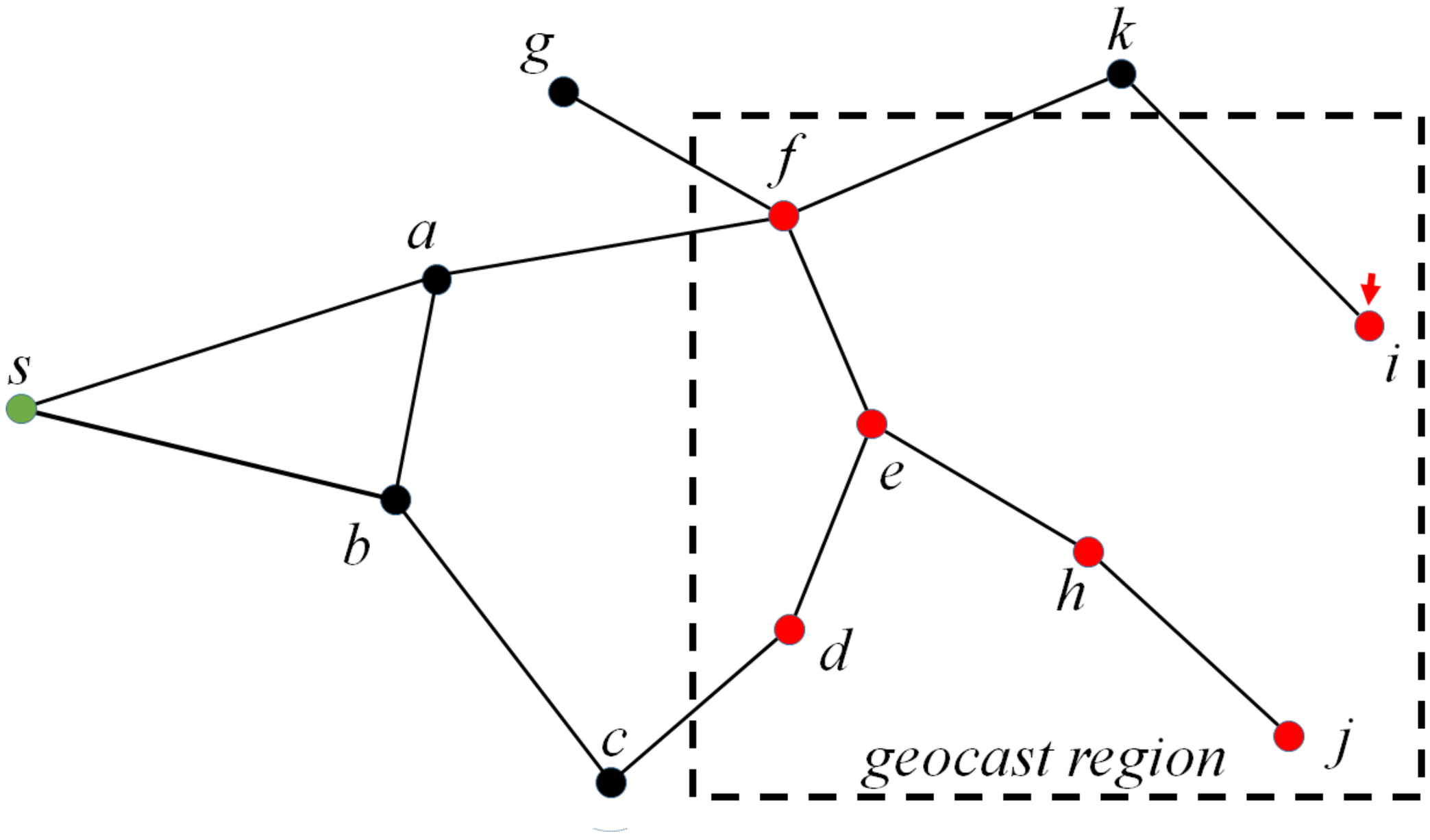
Concurrent Face Routing



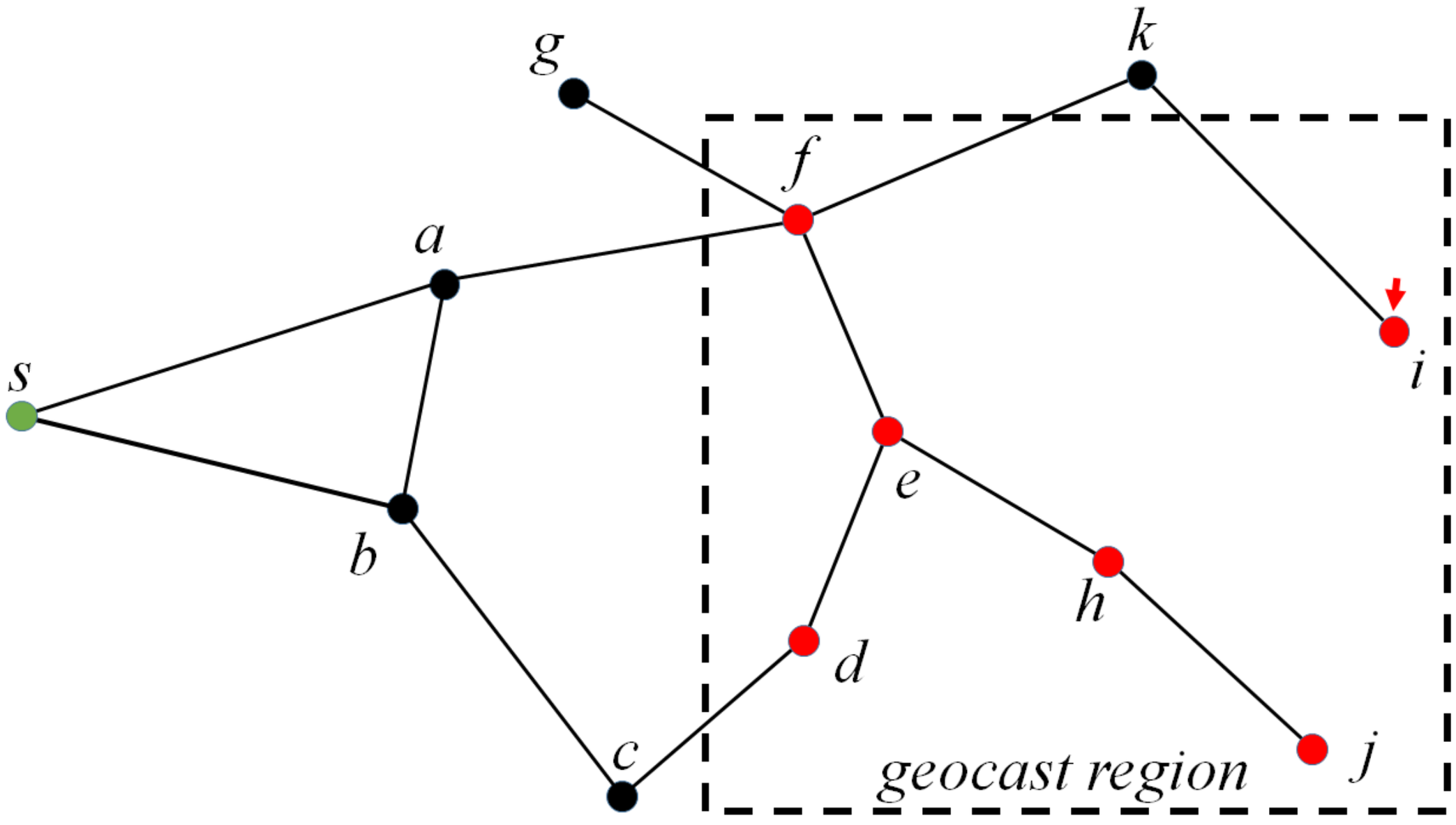
Concurrent Face Routing



Geocasting



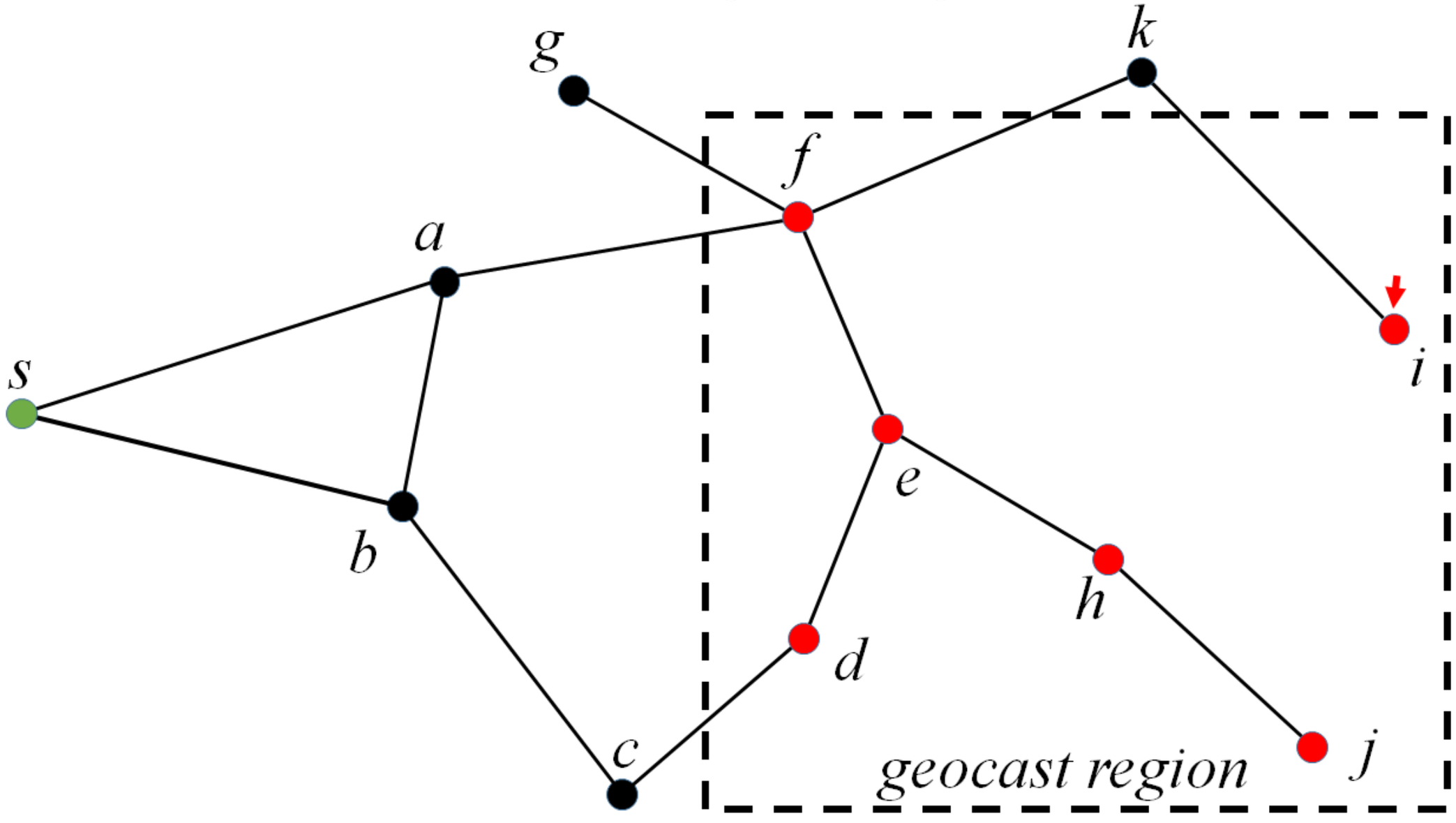
Geocasting



Karim Seada and Ahmed Helmy. Efficient and robust geocasting protocols for sensor networks. Computer Communications, 29(2):151– 161, 2006.

Geocasting

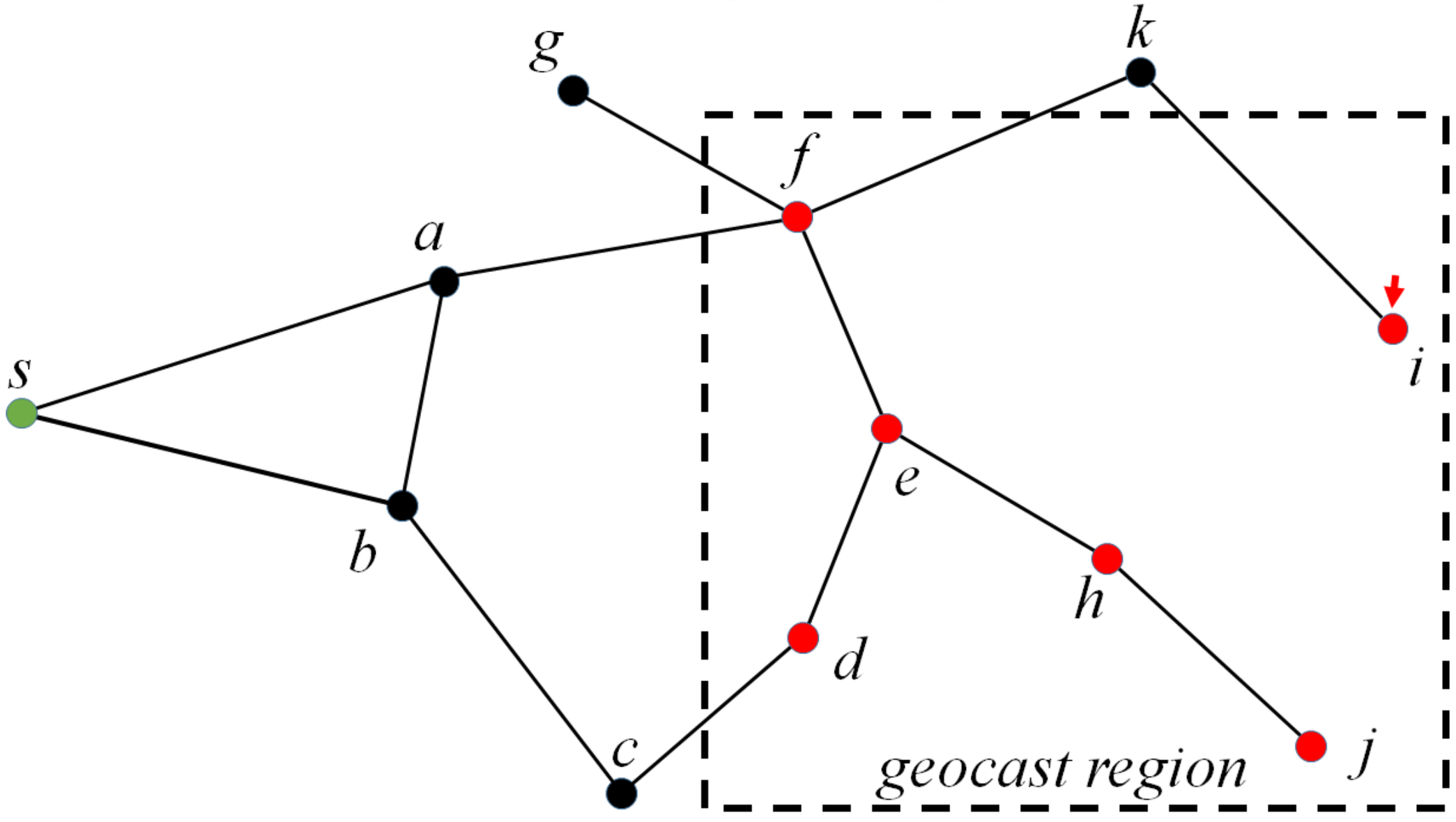
Geometric Unicast, then stateful flooding within region



Karim Seada and Ahmed Helmy. Efficient and robust geocasting protocols for sensor networks. Computer Communications, 29(2):151– 161, 2006.

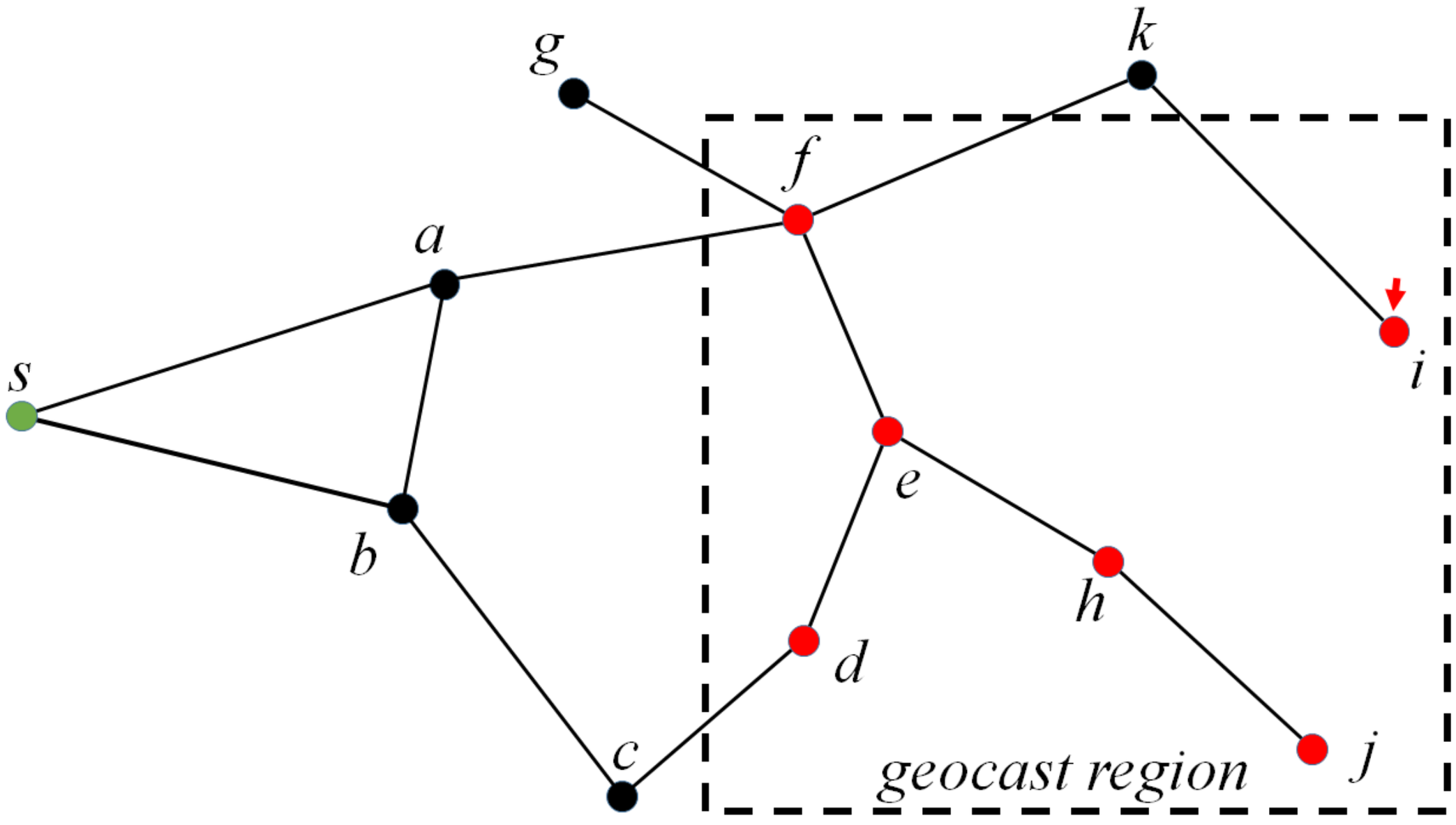
Geocasting

Geometric Unicast, then stateful flooding within region: Stateful, Unreliable



Karim Seada and Ahmed Helmy. Efficient and robust geocasting protocols for sensor networks. Computer Communications, 29(2):151– 161, 2006.

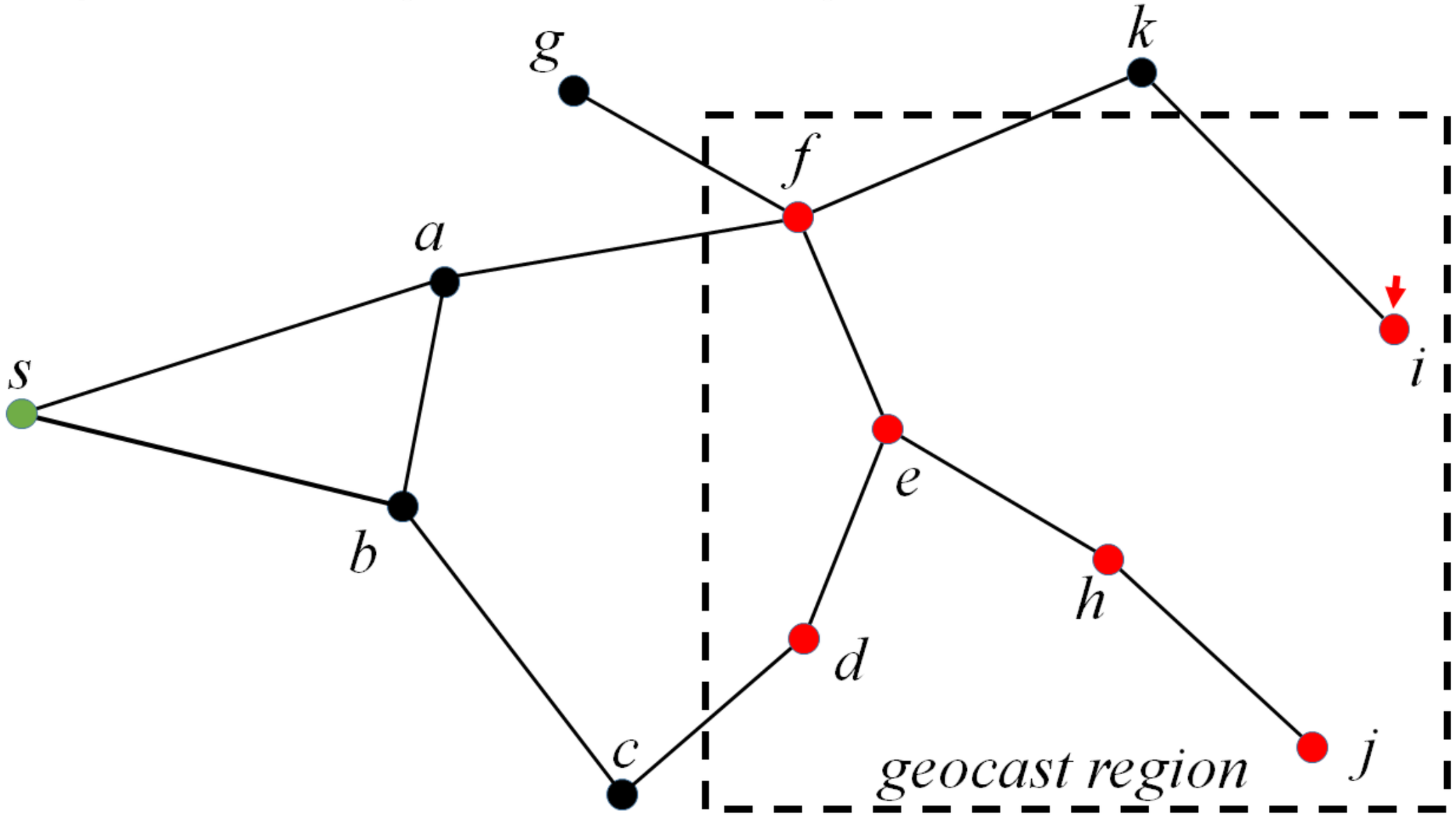
Geocasting



Jie Lian, Kshirasagar Naik, Yunhao Liu, and Lei Chen. Virtual surrounding face geocasting with guaranteed message delivery for ad hoc and sensor networks. In Network Protocols, 2006. ICNP'06. Proceedings of the 2006 14th IEEE International Conference on, pages 198–207. IEEE, 2006.

Geocasting

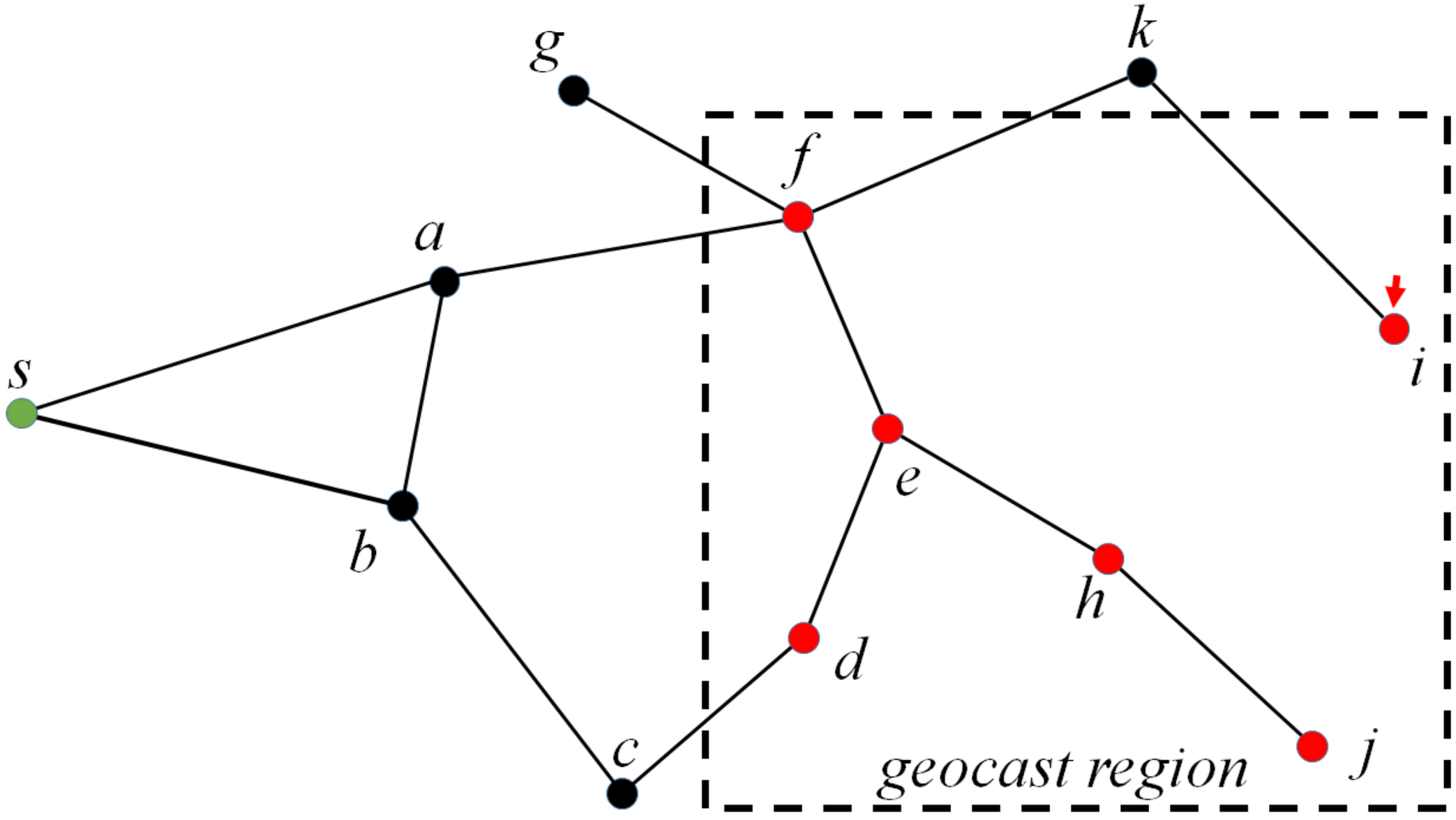
Precompute surrounding faces, unicast to region, then flood



Jie Lian, Kshirasagar Naik, Yunhao Liu, and Lei Chen. Virtual surrounding face geocasting with guaranteed message delivery for ad hoc and sensor networks. In Network Protocols, 2006. ICNP'06. Proceedings of the 2006 14th IEEE International Conference on, pages 198–207. IEEE, 2006.

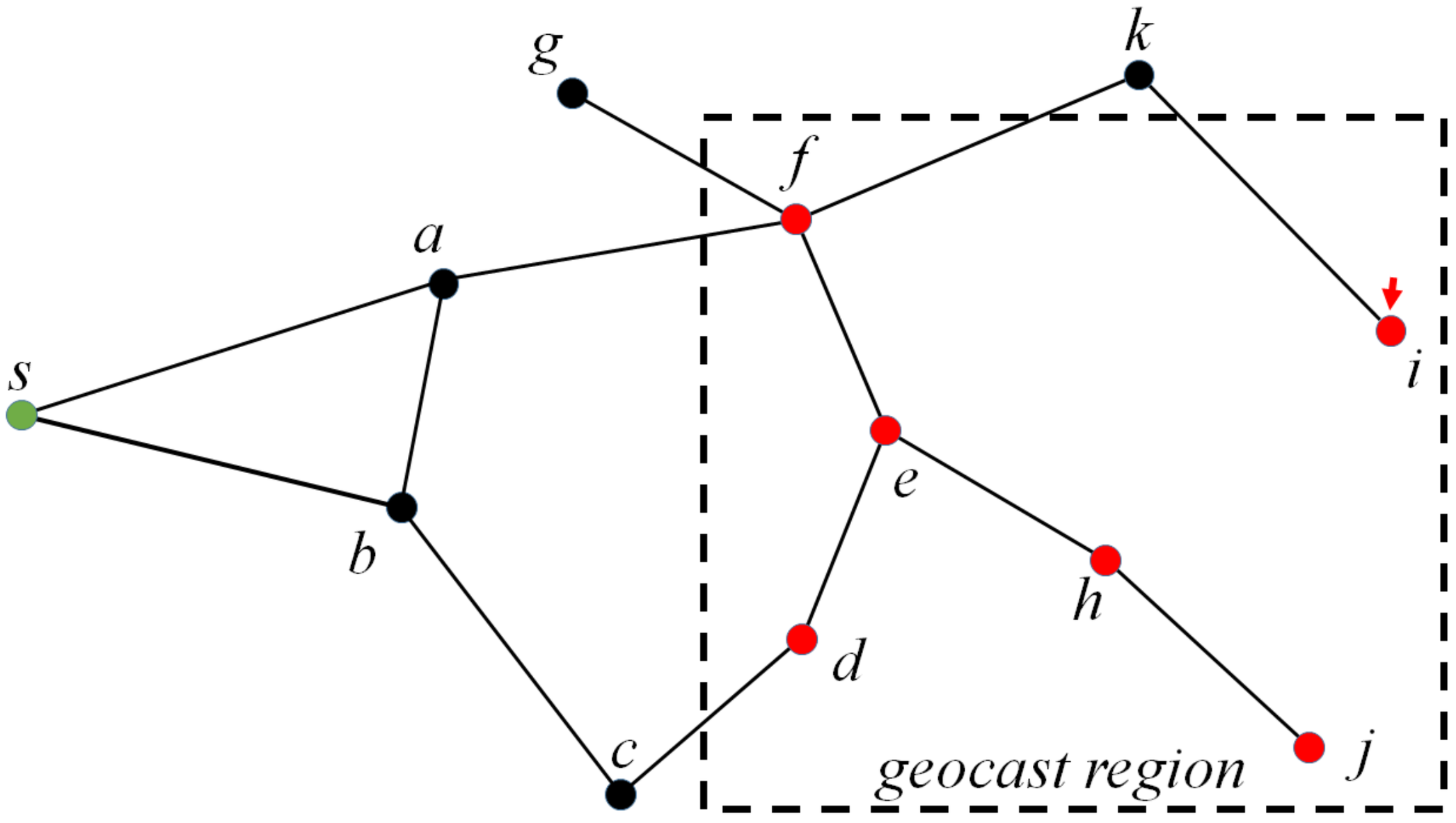
Geocasting

Precompute surrounding faces, unicast to region, then flood: Stateful, Reliable



Jie Lian, Kshirasagar Naik, Yunhao Liu, and Lei Chen. Virtual surrounding face geocasting with guaranteed message delivery for ad hoc and sensor networks. In Network Protocols, 2006. ICNP'06. Proceedings of the 2006 14th IEEE International Conference on, pages 198–207. IEEE, 2006.

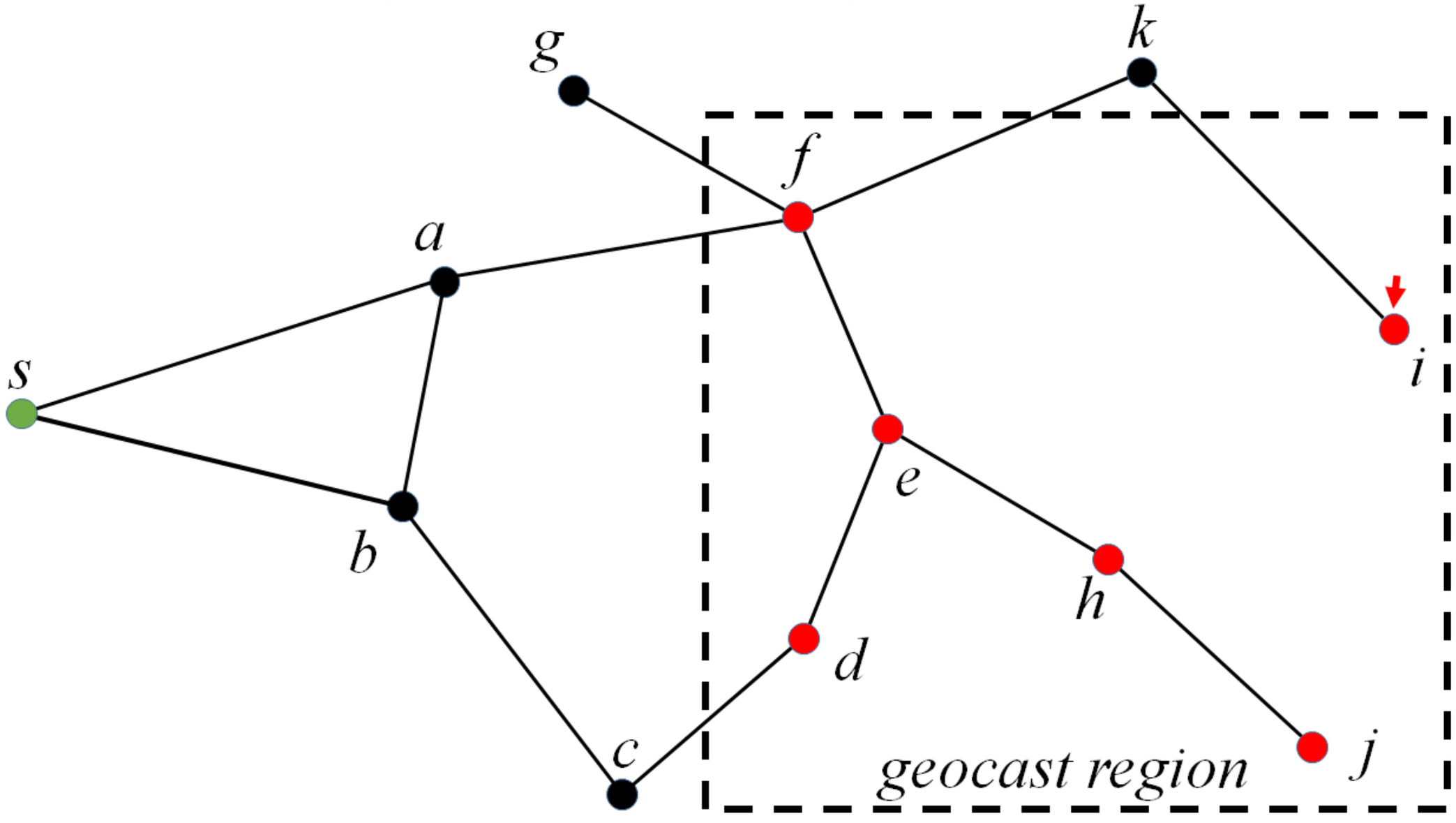
Geocasting



Prosenjit Bose and Pat Morin. An improved algorithm for subdivision traversal without extra storage. International Journal of Computational Geometry and Applications, 12(4):297–308, 2002.

Geocasting

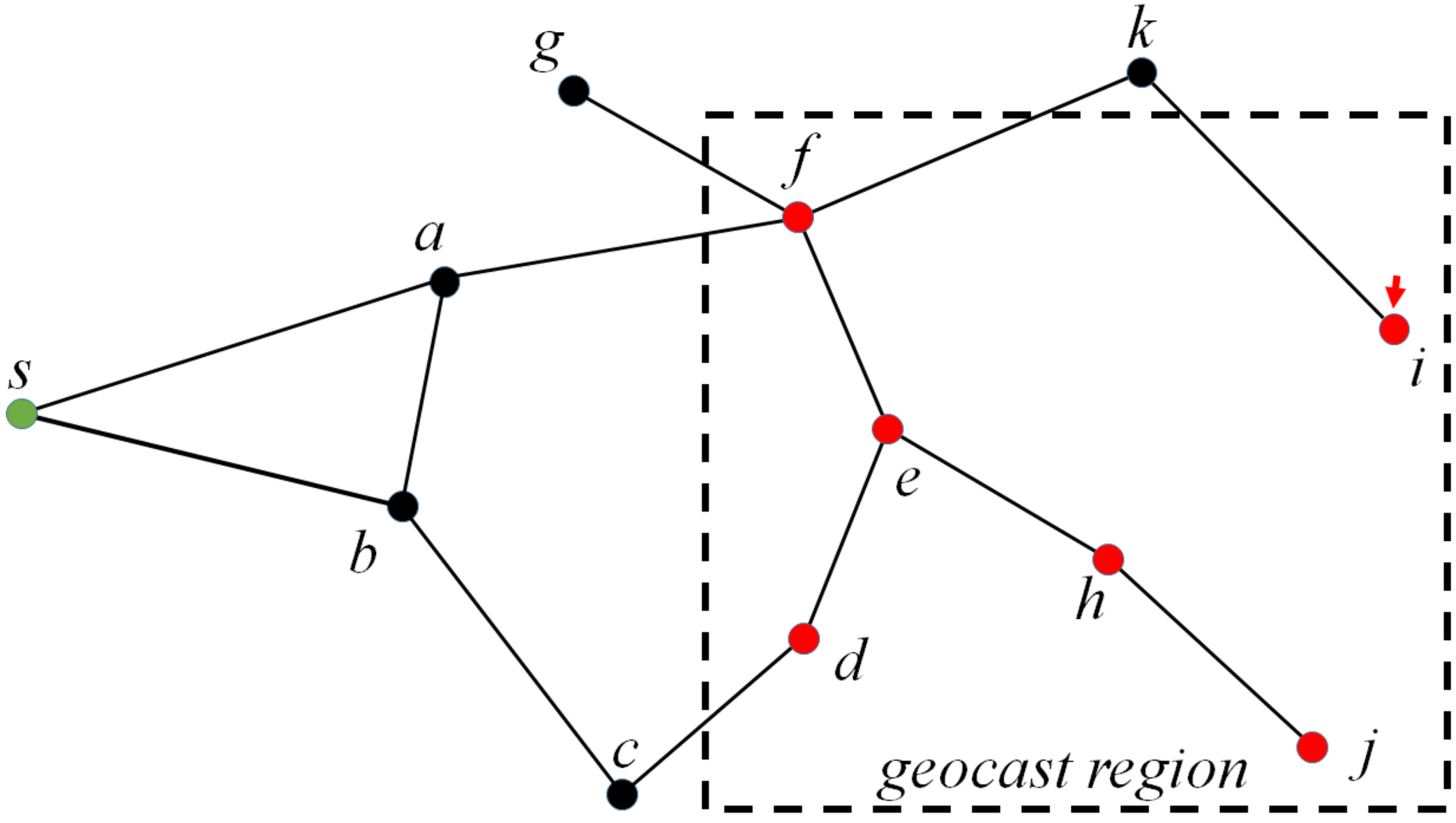
Assumes subdivisions (edge belong to 2 faces)



Prosenjit Bose and Pat Morin. An improved algorithm for subdivision traversal without extra storage. International Journal of Computational Geometry and Applications, 12(4):297–308, 2002.

Geocasting

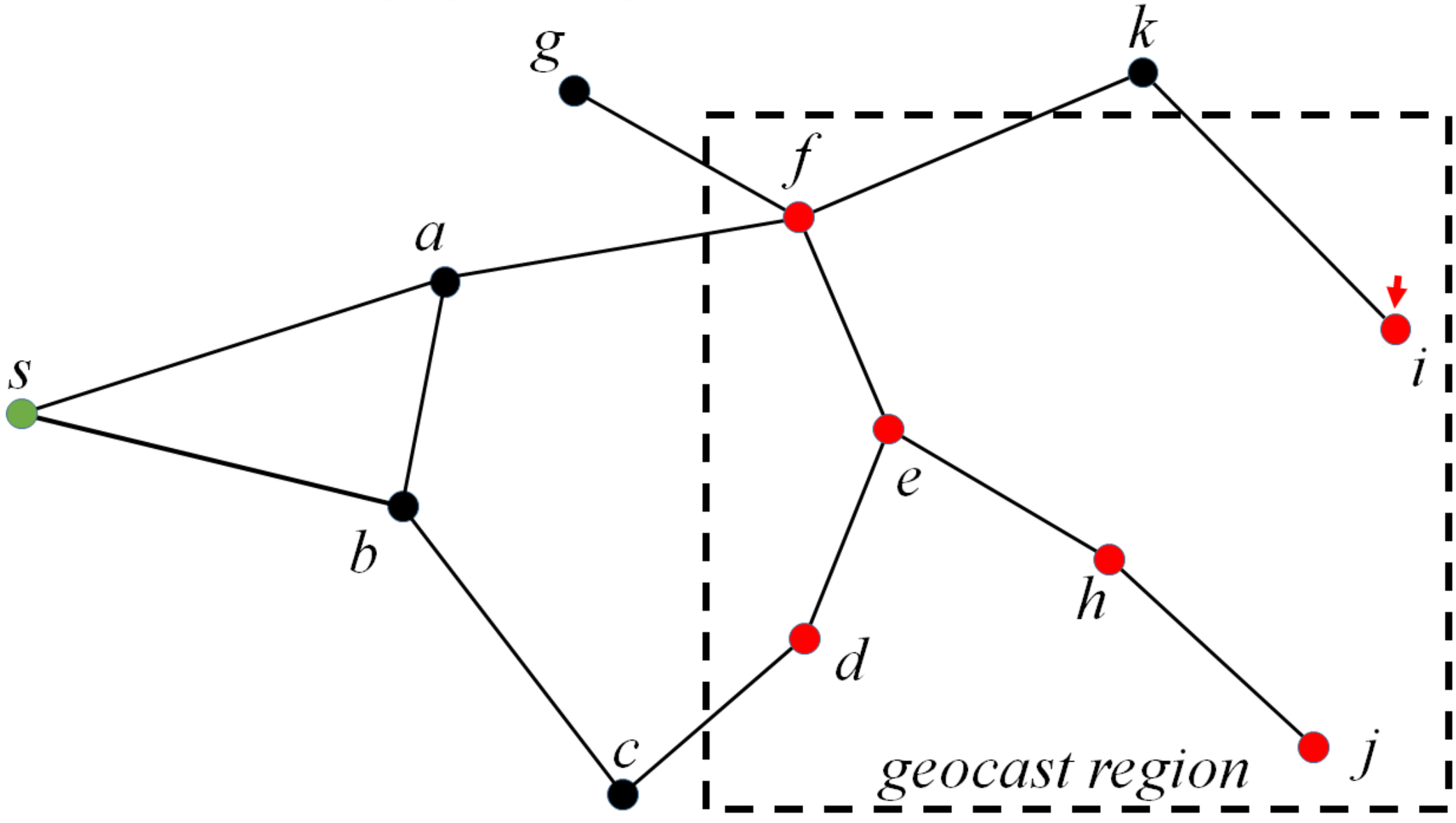
Assumes subdivisions (edge belong to 2 faces): Stateless, Reliable



Prosenjit Bose and Pat Morin. An improved algorithm for subdivision traversal without extra storage. International Journal of Computational Geometry and Applications, 12(4):297–308, 2002.

Geocasting

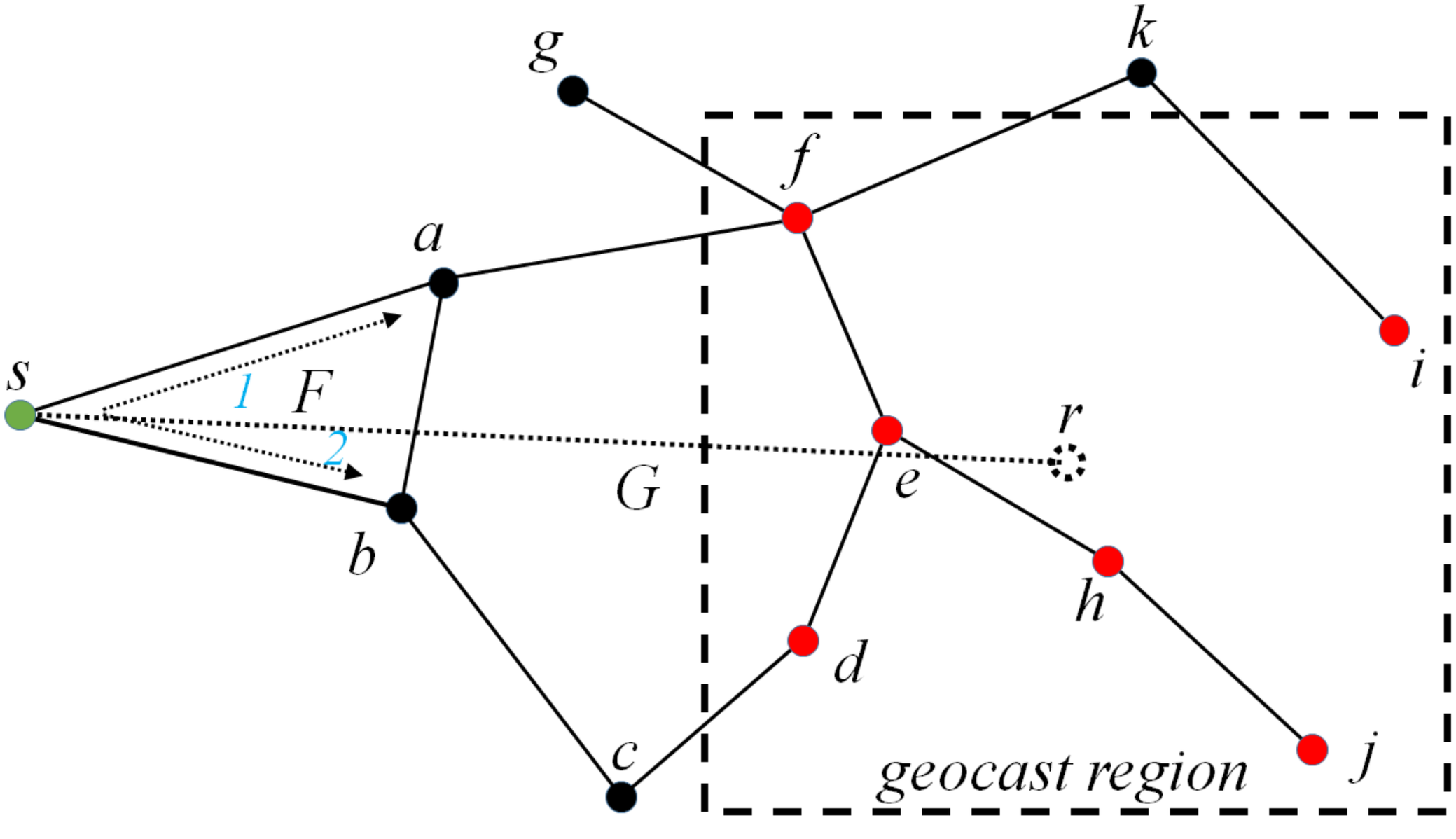
Assumes subdivisions (edge belong to 2 faces): Stateless, Reliable, May Livelock



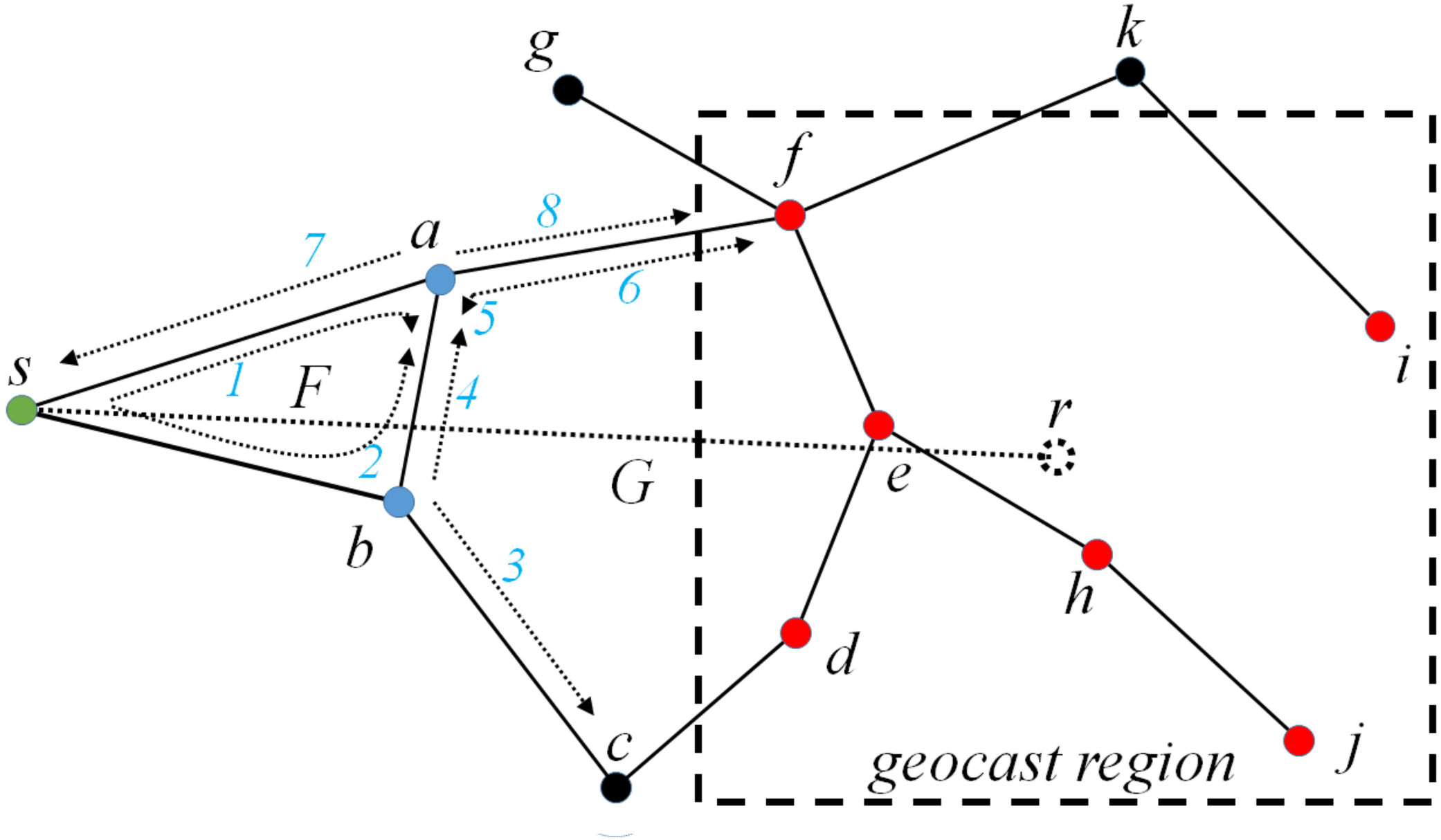
Prosenjit Bose and Pat Morin. An improved algorithm for subdivision traversal without extra storage. International Journal of Computational Geometry and Applications, 12(4):297–308, 2002.

Our Contributions

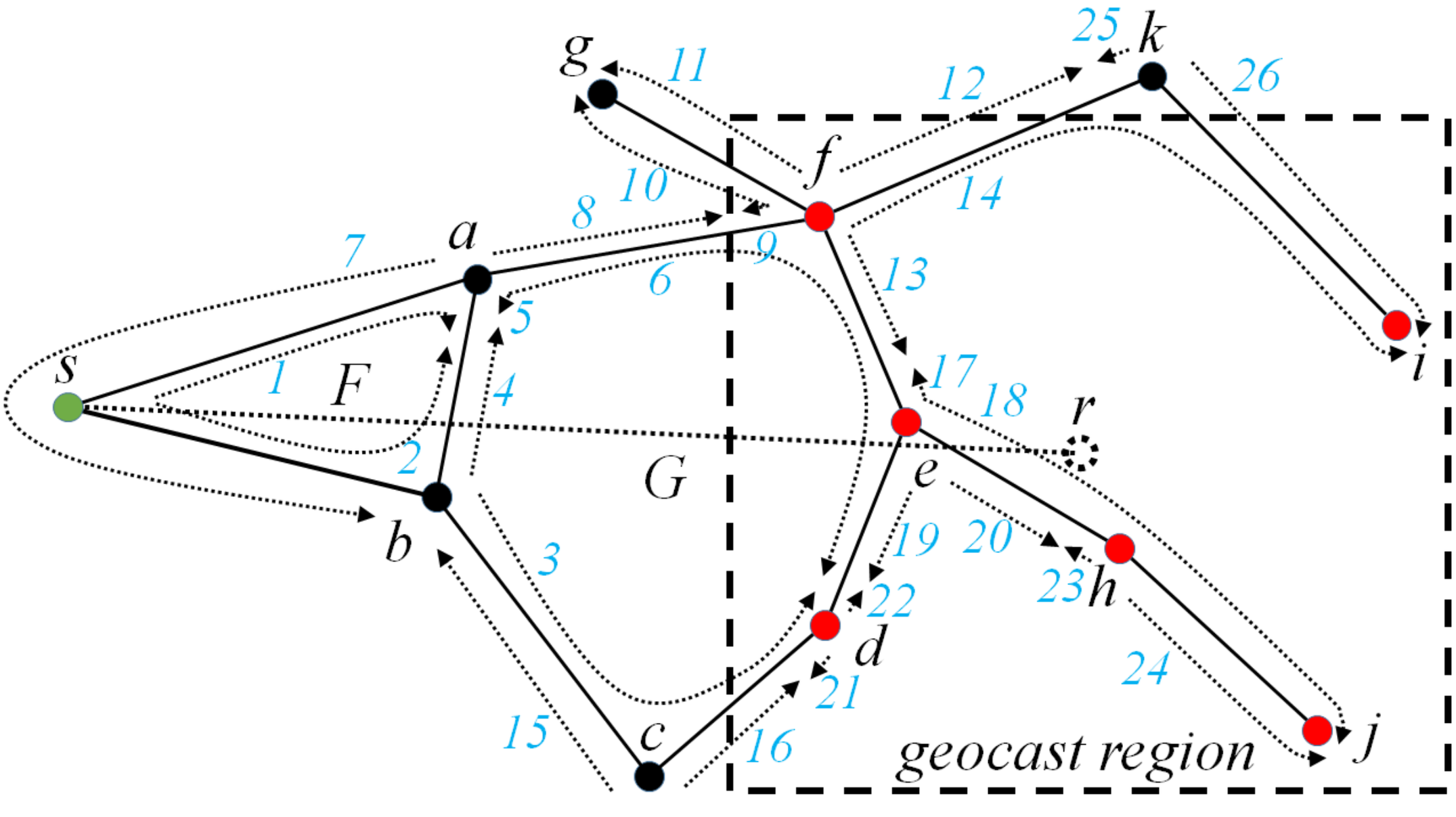
Stateless Planar Geocast



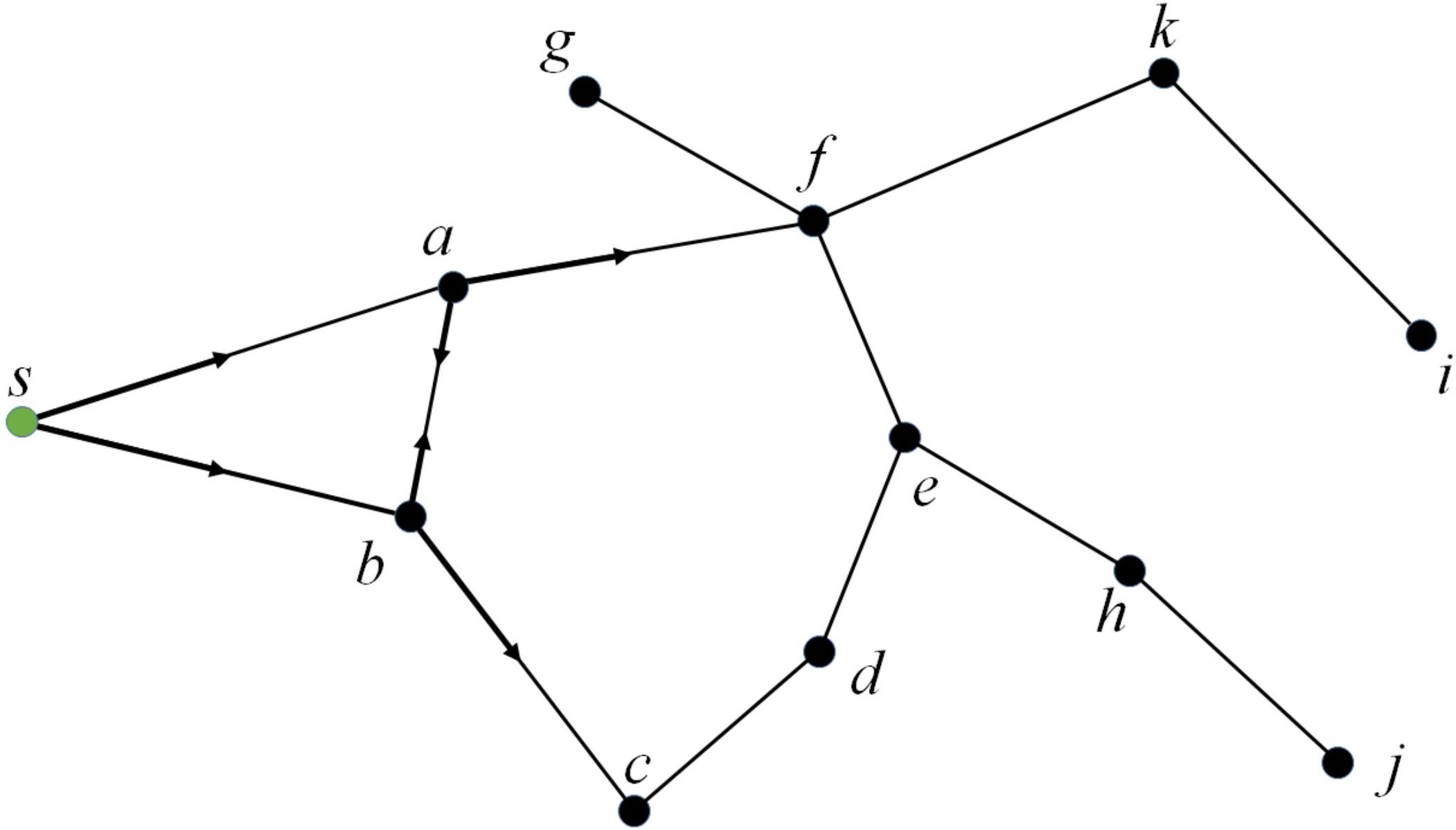
Stateless Planar Geocast



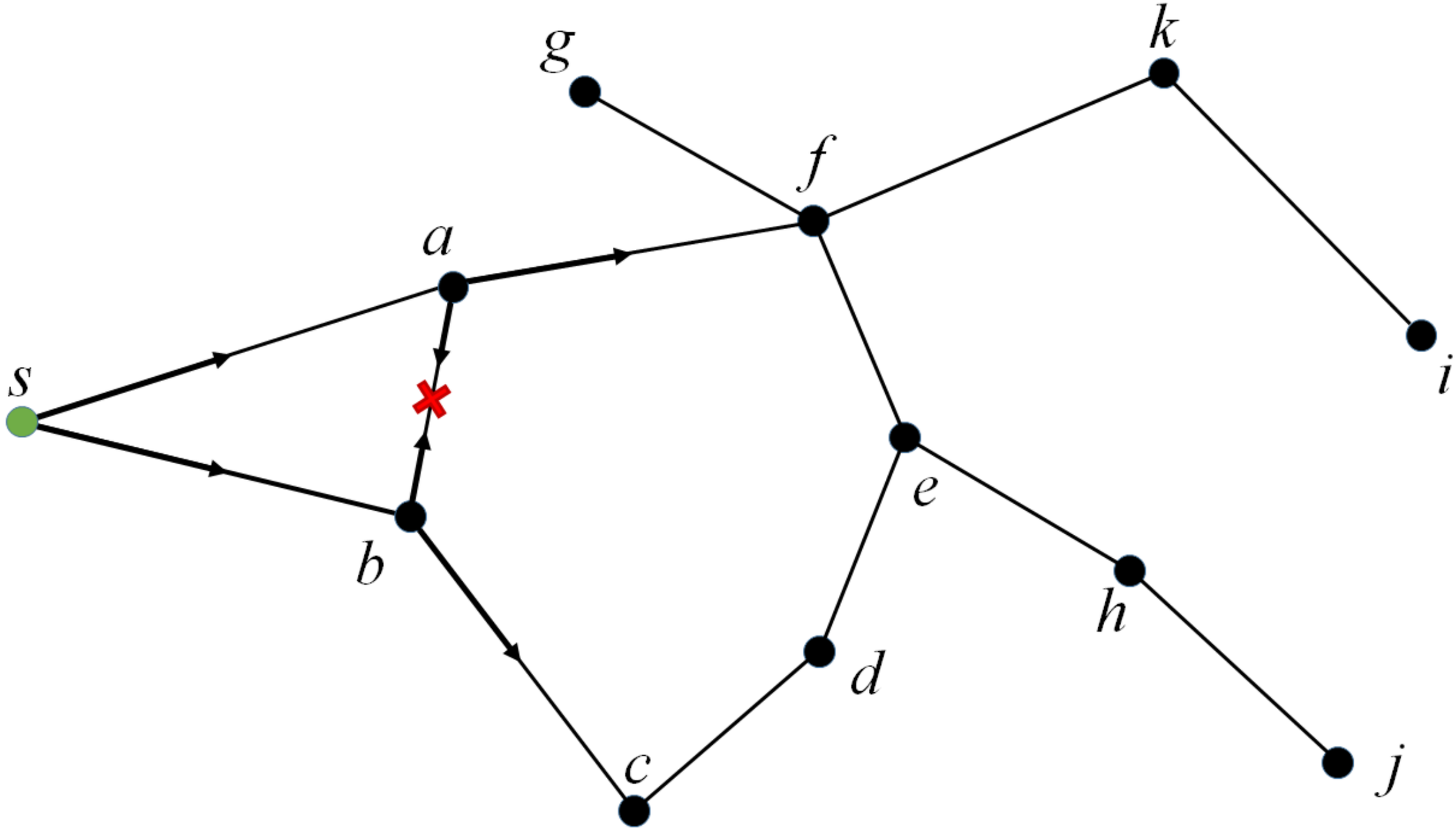
Stateless Planar Geocast



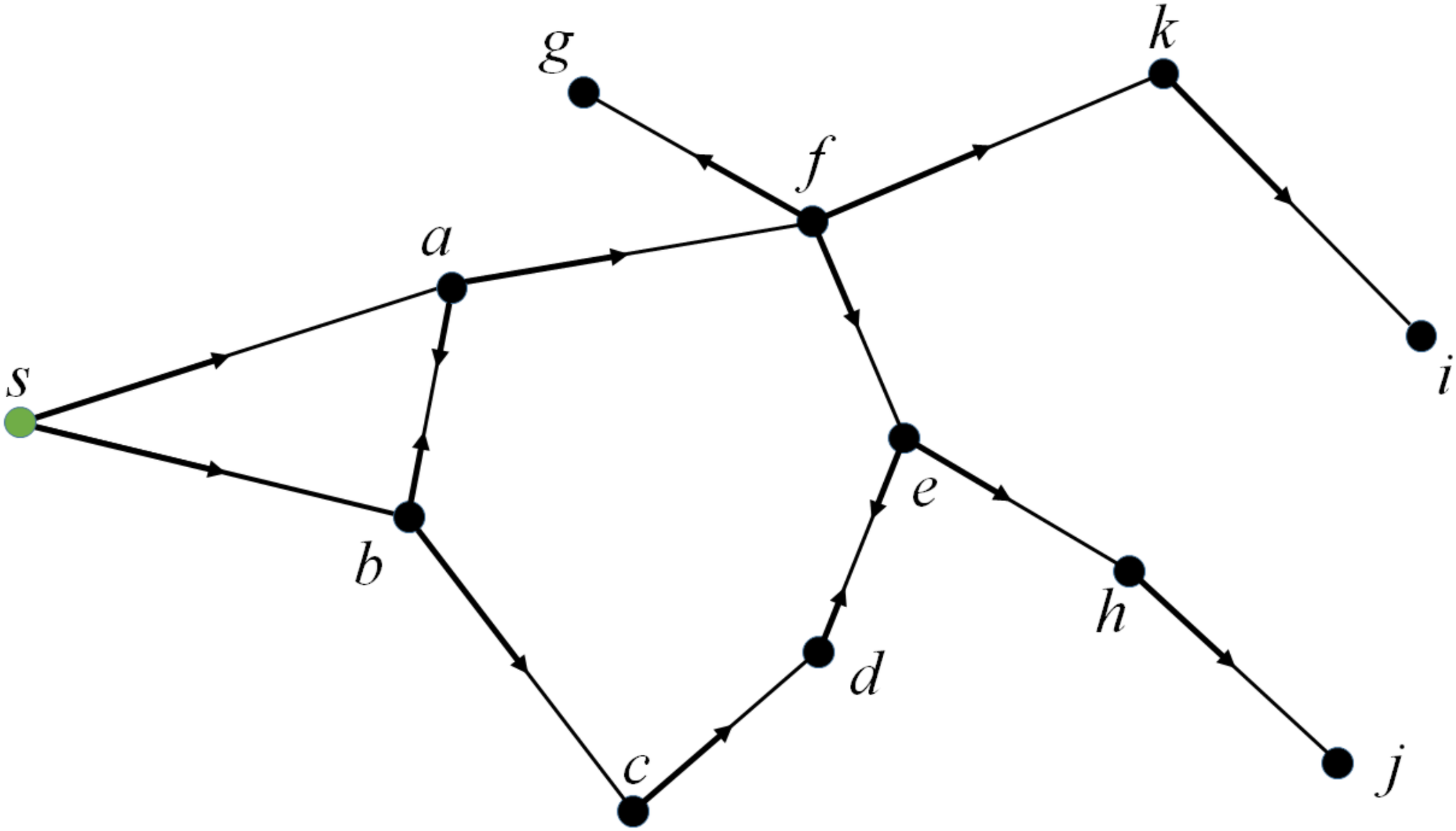
Stateless Flooding



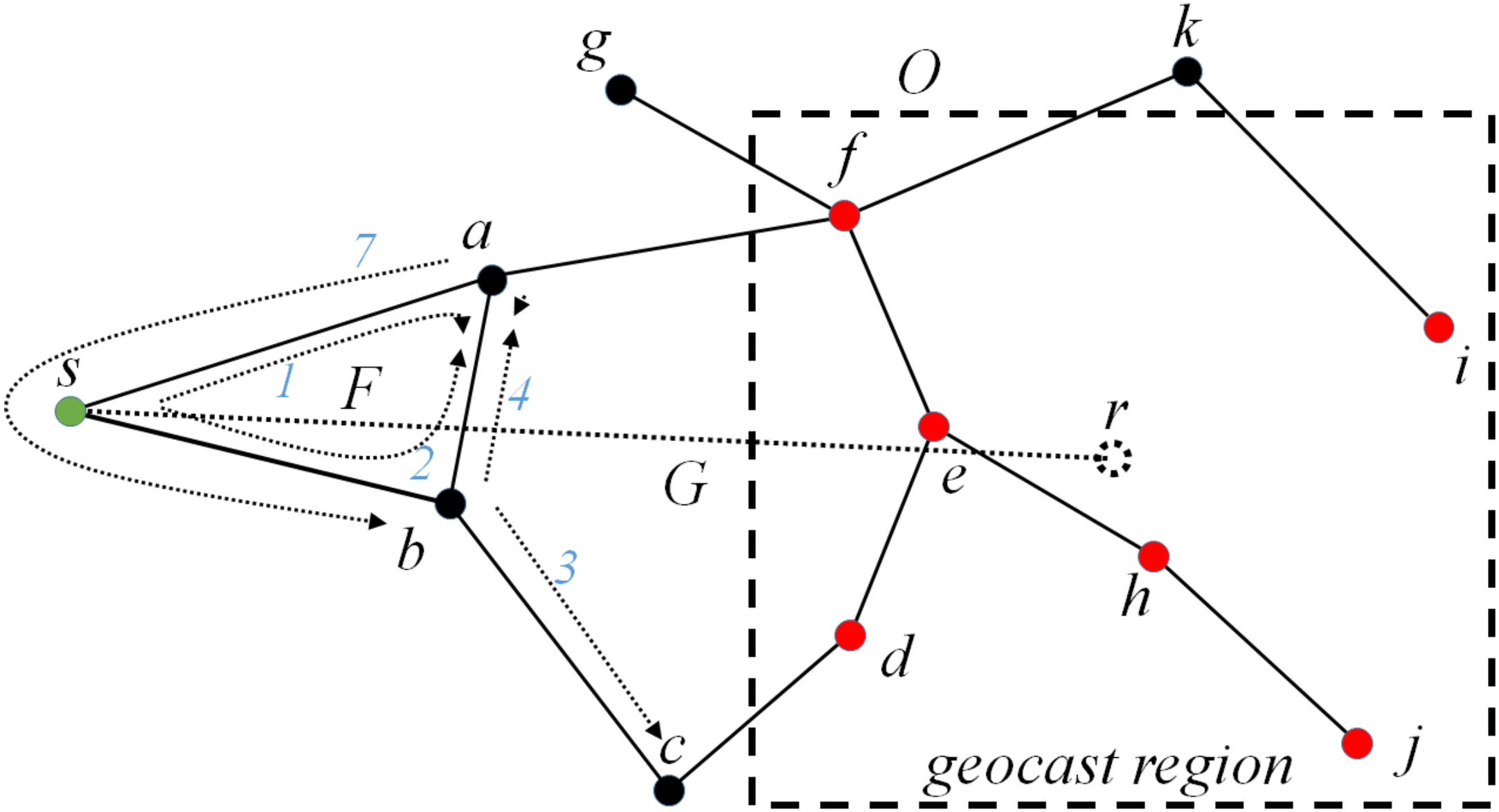
Stateless Flooding



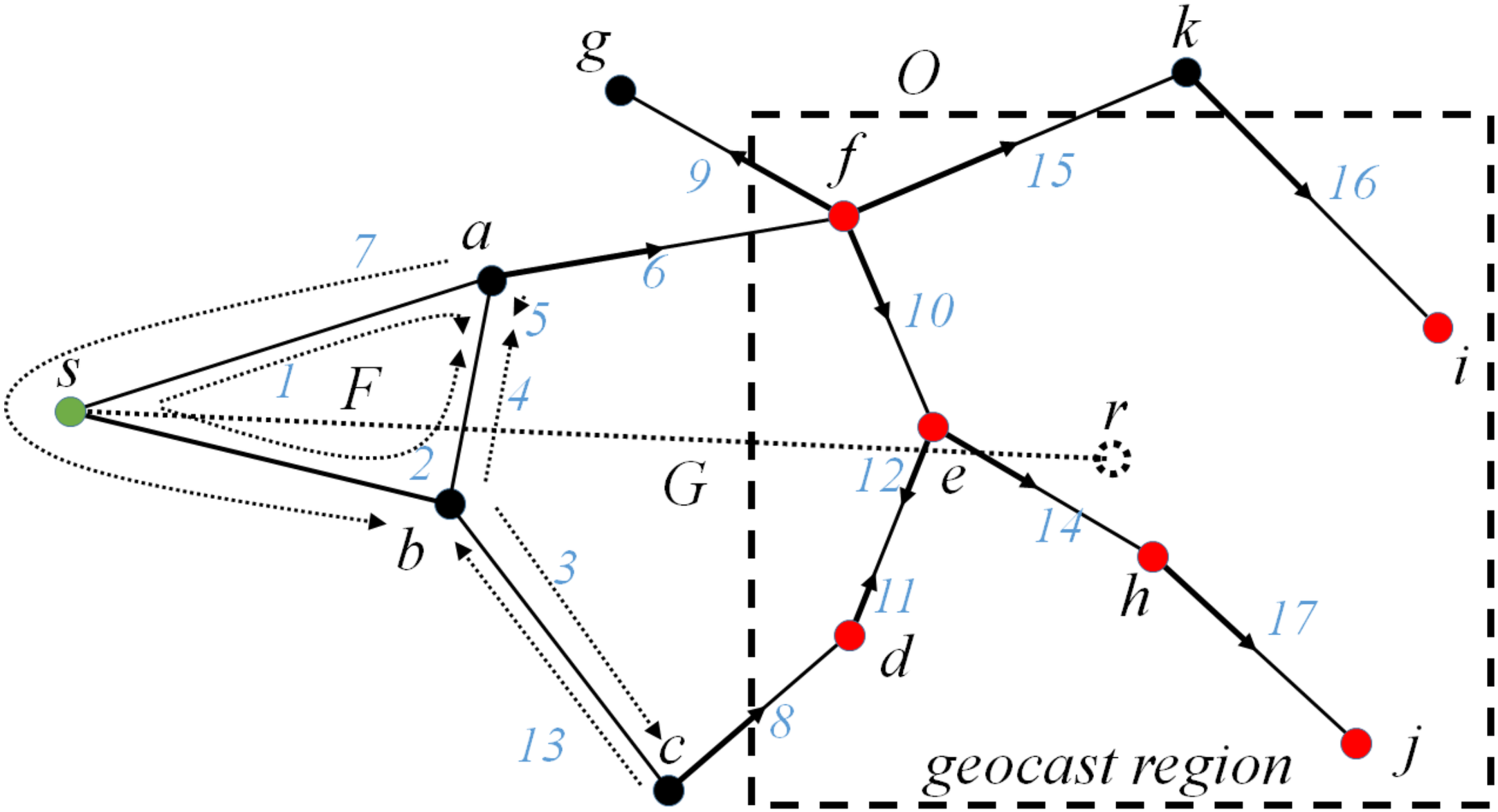
Stateless Flooding



SPG + Stateless Flooding



SPG + Stateless Flooding



Theoretical Complexity

- **Guaranteed delivery** to all nodes in the target area (if connected to the source)

- **Latency** is quadratic in distance to destination (**optimal**)

- **2E** messages in the **worst** case (E messages for SF), but much better for UDG networks

Experimental Results

Abstract vs. Concrete Simulation

- **Abstract**
  - Instantaneous message transmission, no implementation details
  - Theoretical performance
- **Concrete**
  - Radio communication, Network protocol stack
  - Practical performance aspects

Abstract vs. Concrete Simulation

- **Abstract**

Kuhn, Wattenhofer, Zhang, and Zollinger. Geometric ad-hoc routing: Of theory and practice. In PODC: 22th ACM SIGACT-SIGOPS Symposium on Principles of Distributed Computing, 2003.

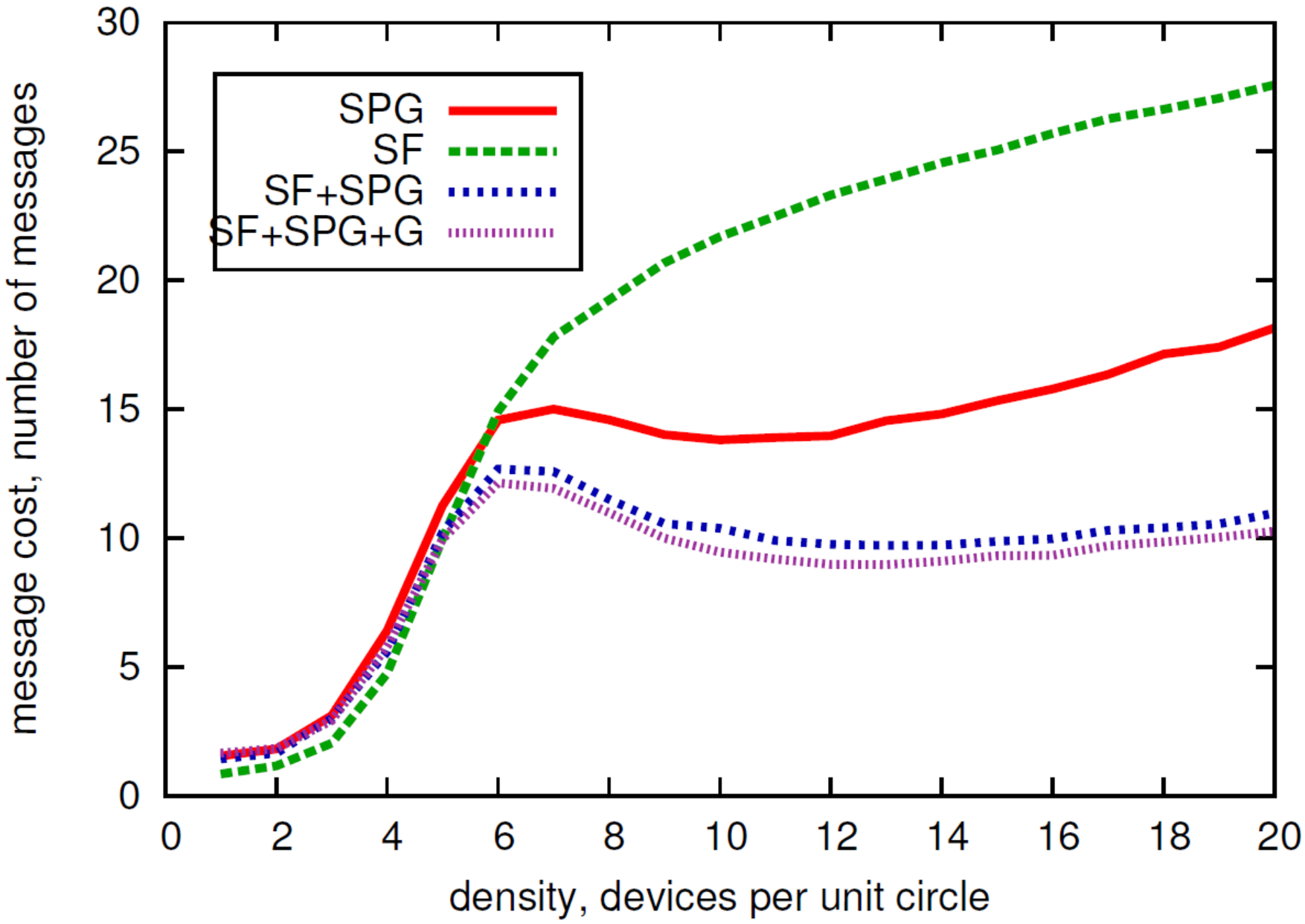
  - Instantaneous message transmission, no implementation details
  - Theoretical performance

- **Concrete**

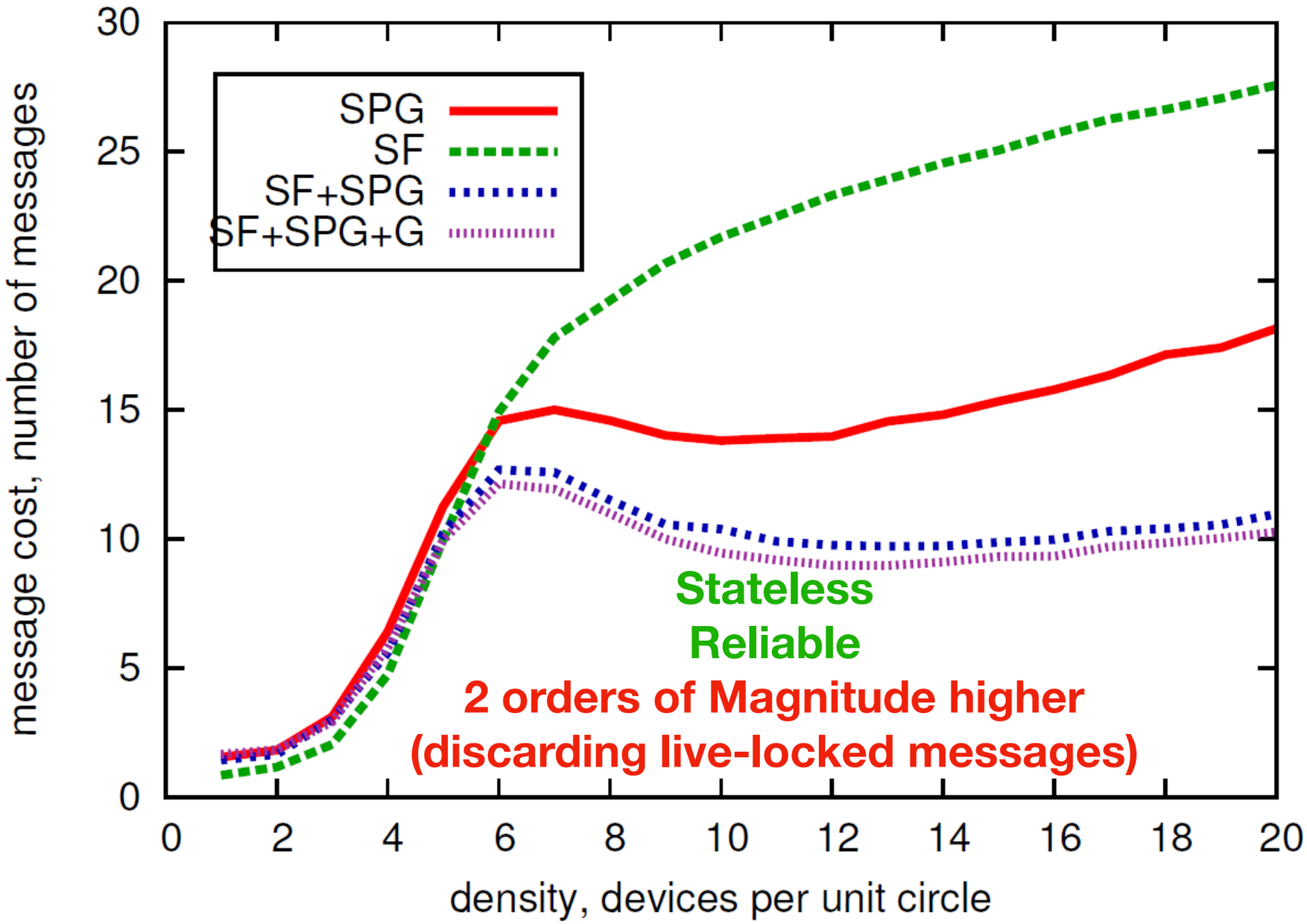
Elyes Ben Hamida, Guillaume Chelius, and Jean-Marie Gorce. On the complexity of an accurate and precise performance evaluation of wire- less networks using simulations. In Proceedings of the 11th international symposium on Modeling, analysis and simulation of wireless and mobile systems, pages 395–402. ACM, 2008.

  - Radio communication, Network protocol stack
  - Practical performance aspects

Abstract: Overhead by Density

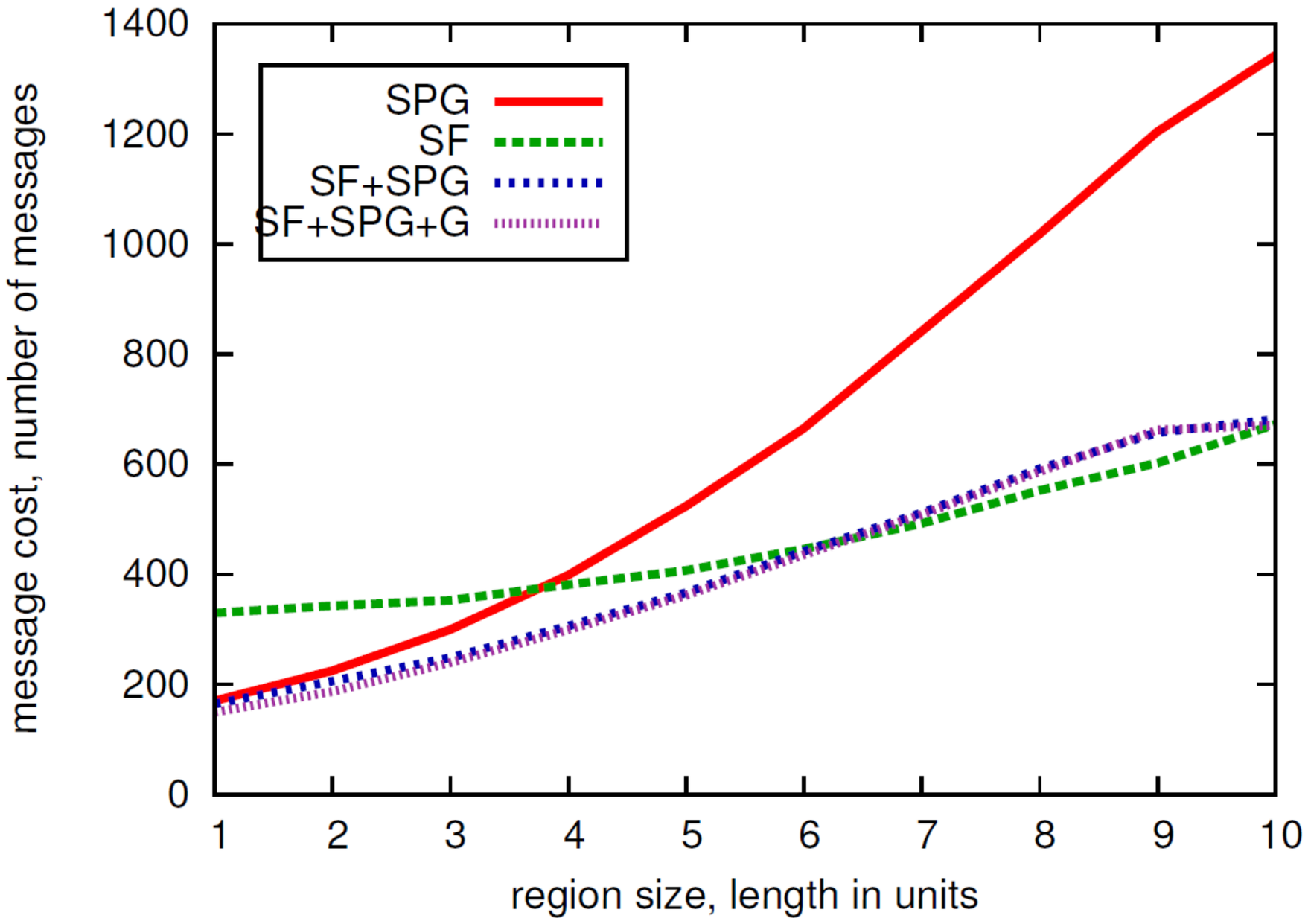


Abstract: Overhead by Density

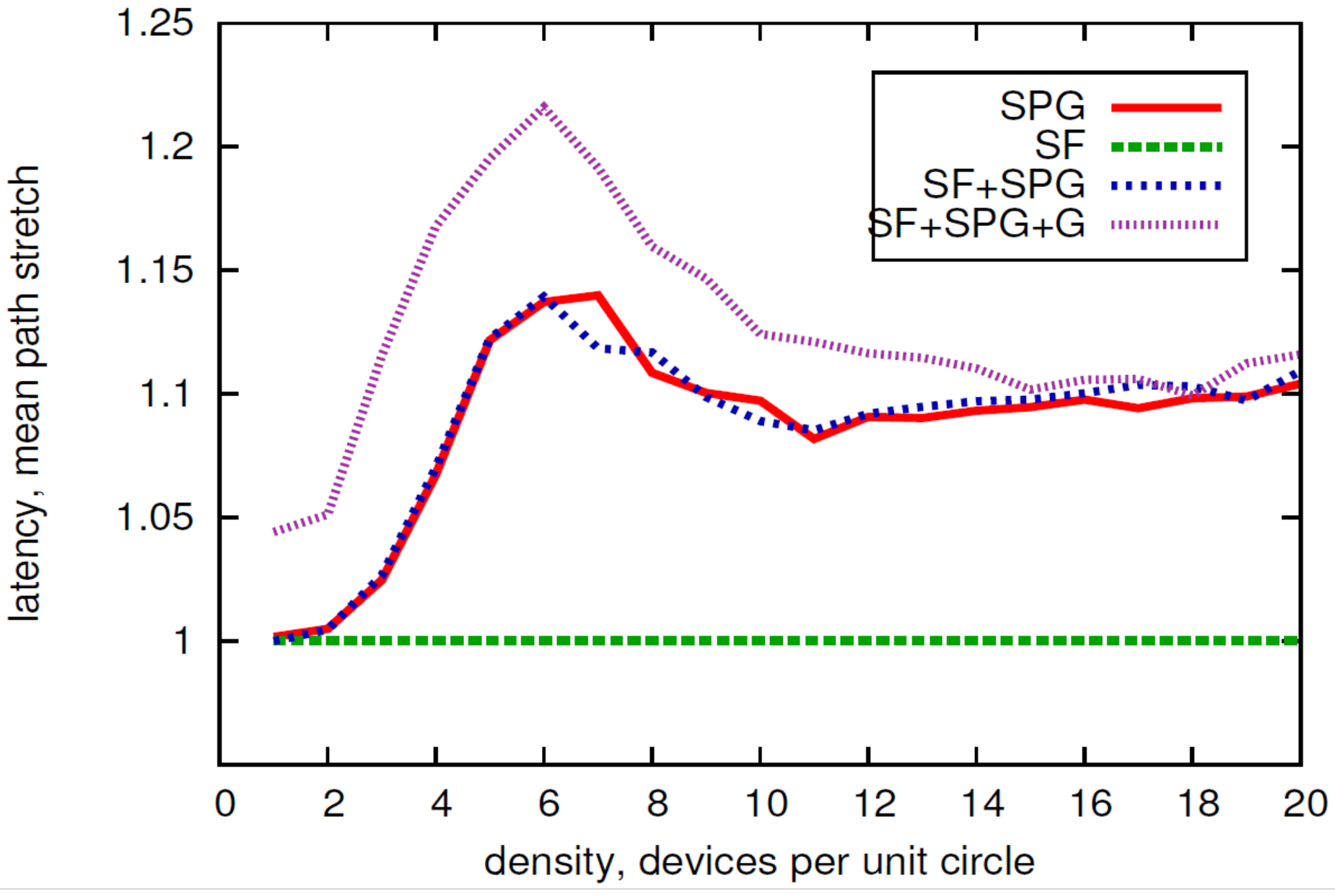


Prosenjit Bose and Pat Morin. An improved algorithm for subdivision traversal without extra storage. International Journal of Computational Geometry and Applications, 12(4):297–308, 2002.

Abstract: Overhead by Region Size



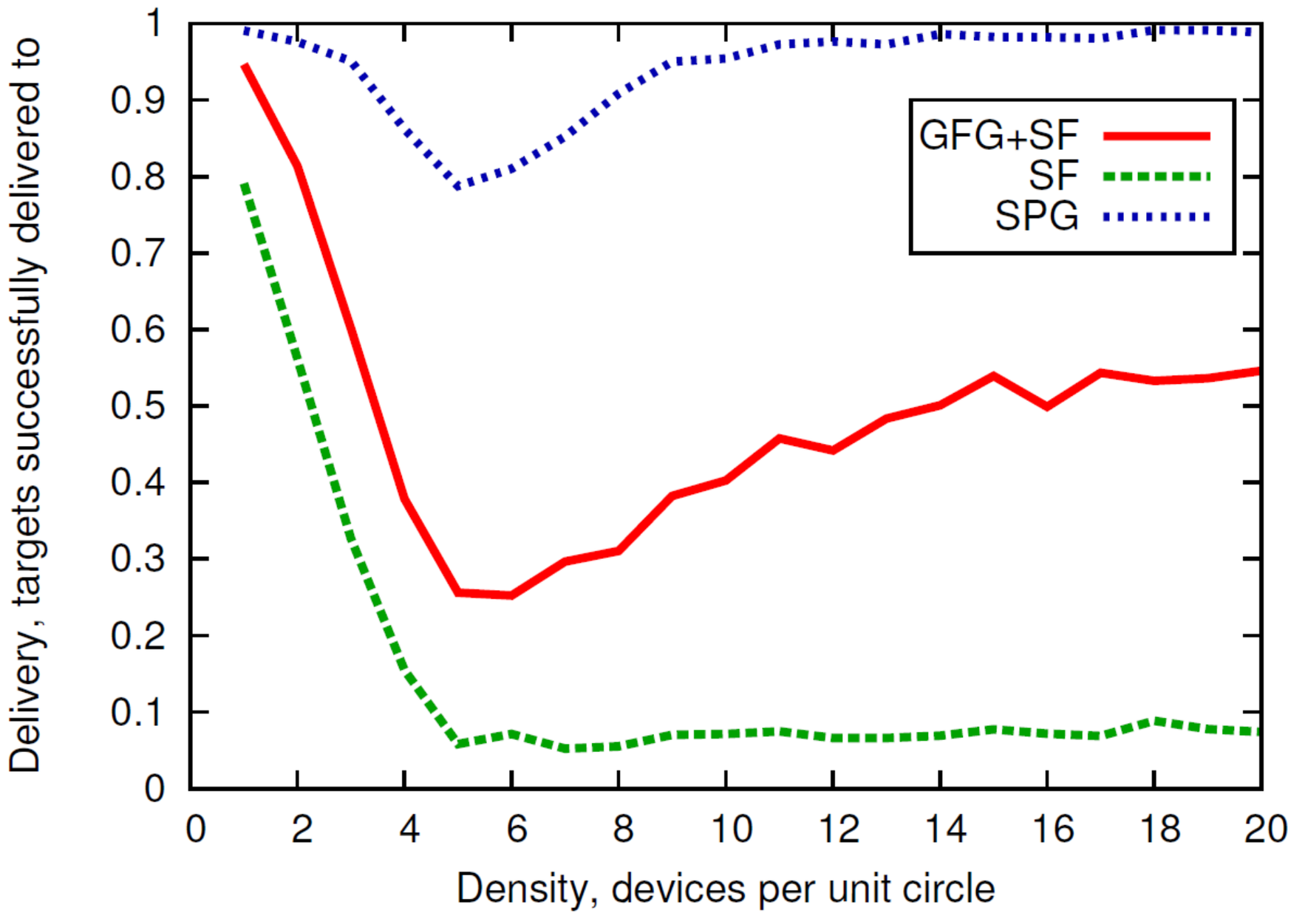
Abstract: Latency By Density



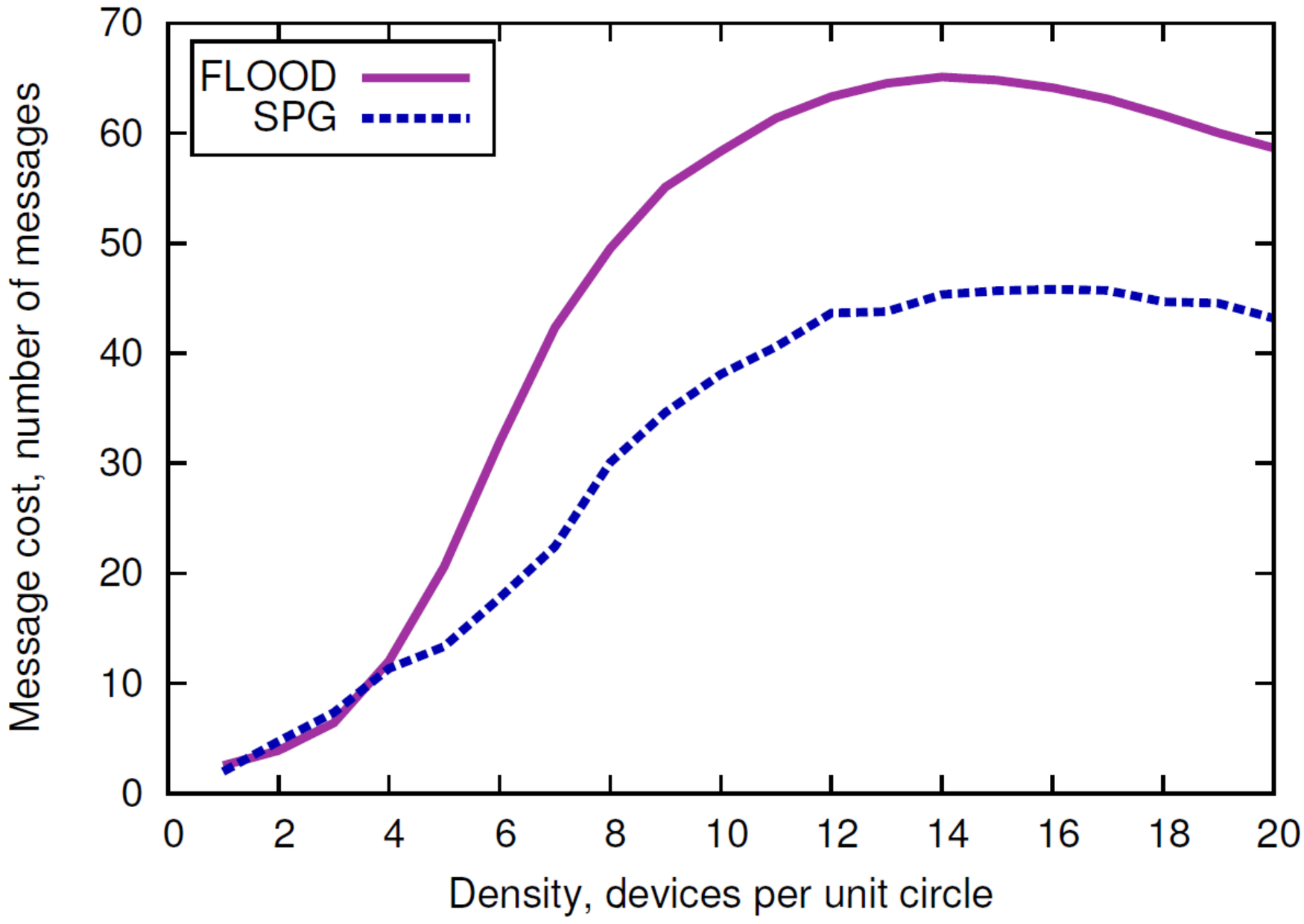
Abstract: Analysis

- **SPG** achieves near optimal latency
- The use of **SF** within the region improves overhead
- The use of **G** lessens concurrency and increases latency

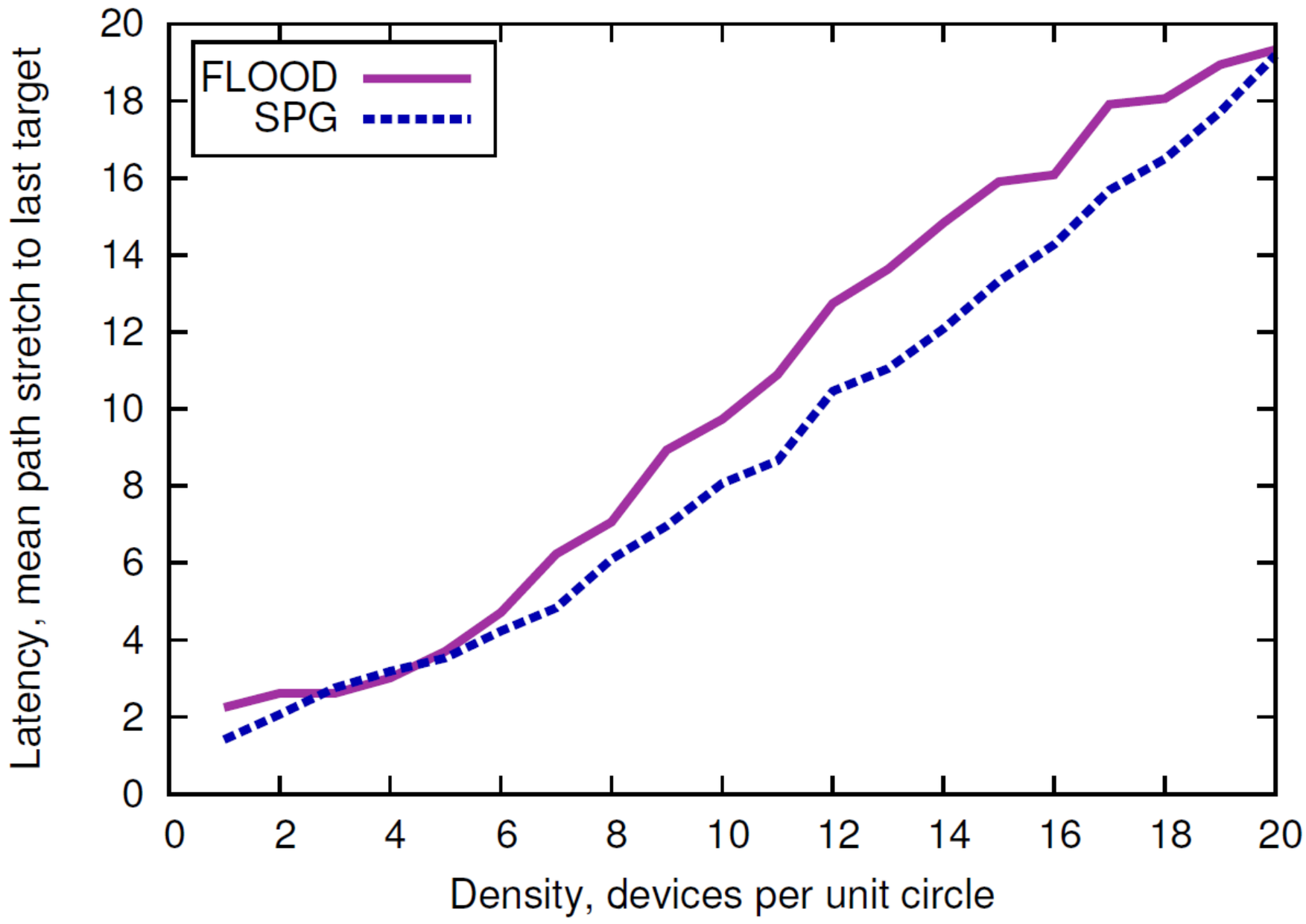
Concrete: Delivery Ratio



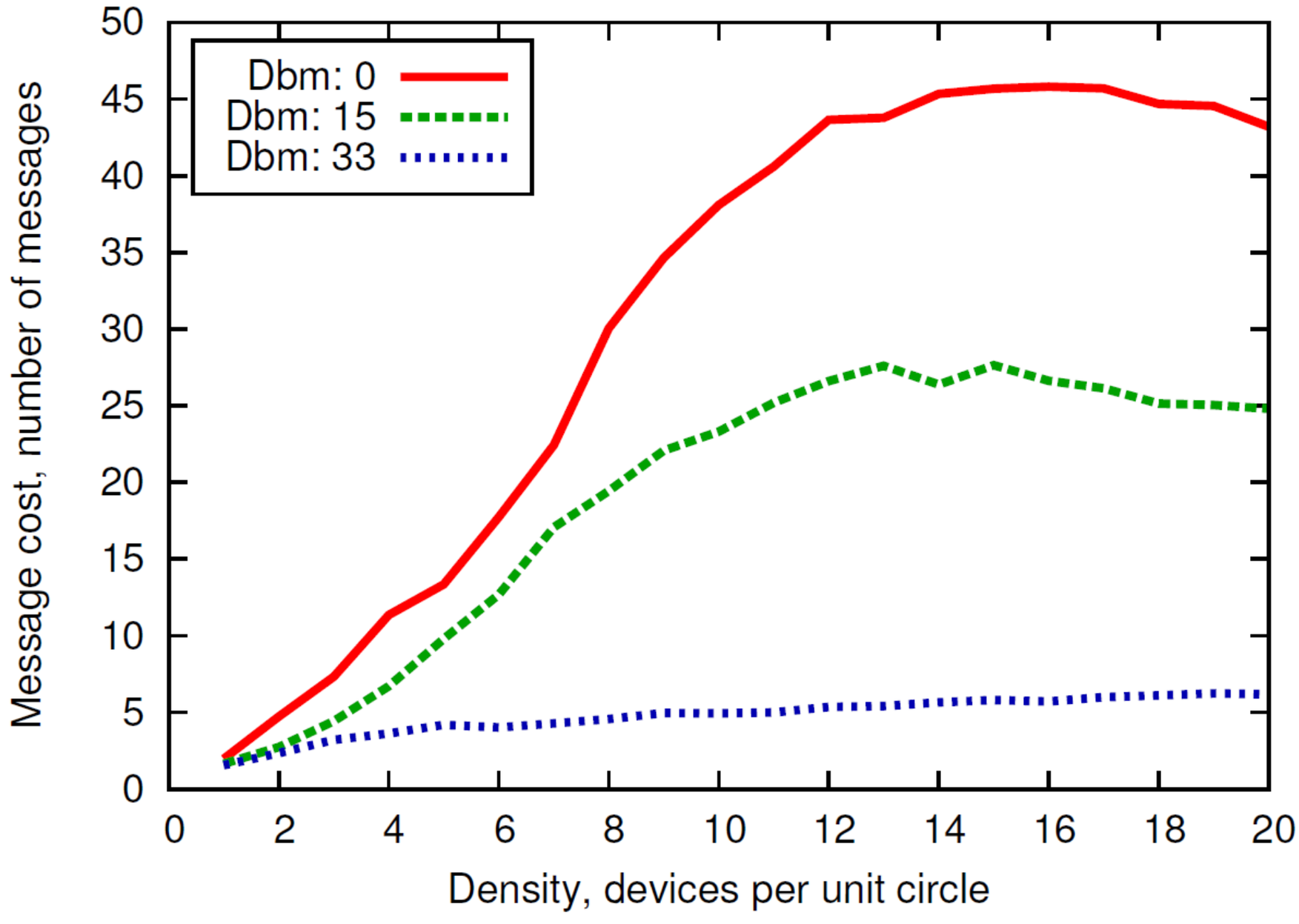
Concrete: Overhead by Density



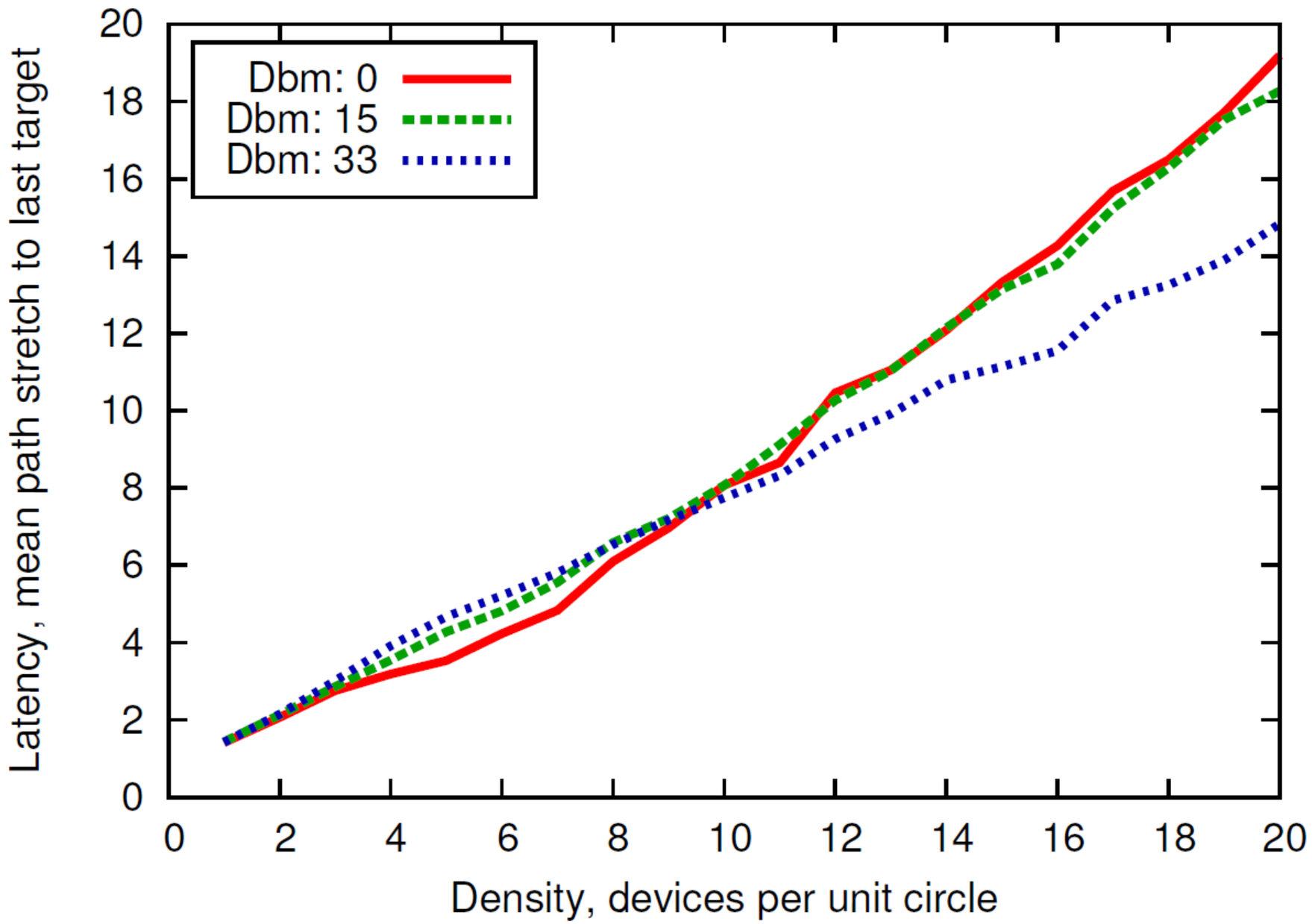
Concrete: Latency by Density



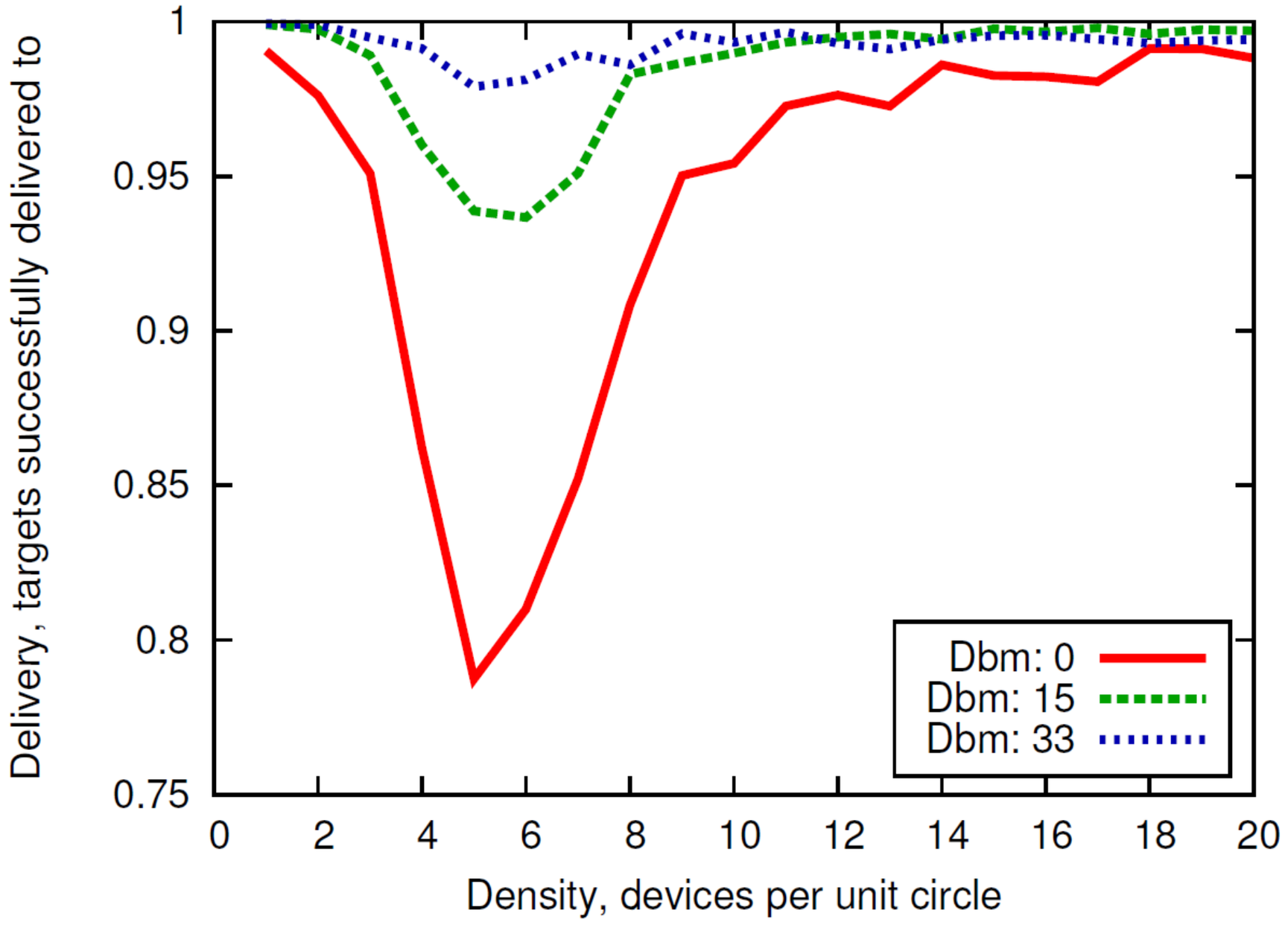
Concrete: Overhead by Density and Signal Strength



Concrete: Latency by Density and Signal Strength



Concrete: Delivery by Density and Signal Strength



Concrete: Analysis

- **SPG** is reliable
- **SPG** has less packet collision than flooding, for improved latency and reduced overhead
- Higher signal strength leads to higher probability to reach next hop

Conclusion

- **Concurrent face routing** is an interesting building block for ad hoc routing
- In **Abstract**, fast but costly
- In **Concrete**, not the fastest, but increased reliability
- Source code and data:

`http://www.cs.kent.edu/~mikhail/Research/`

Thank You