Concurrent Geometric Multicasting

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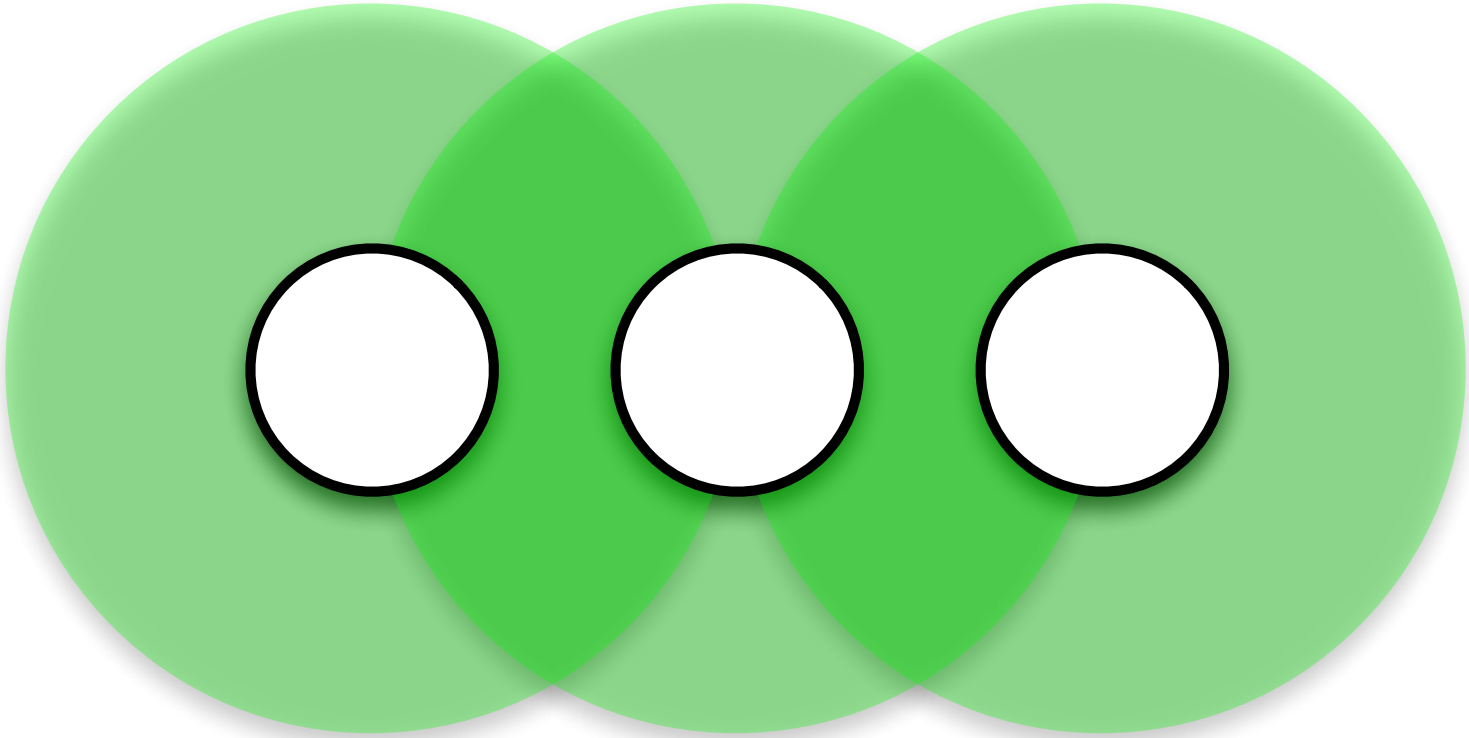
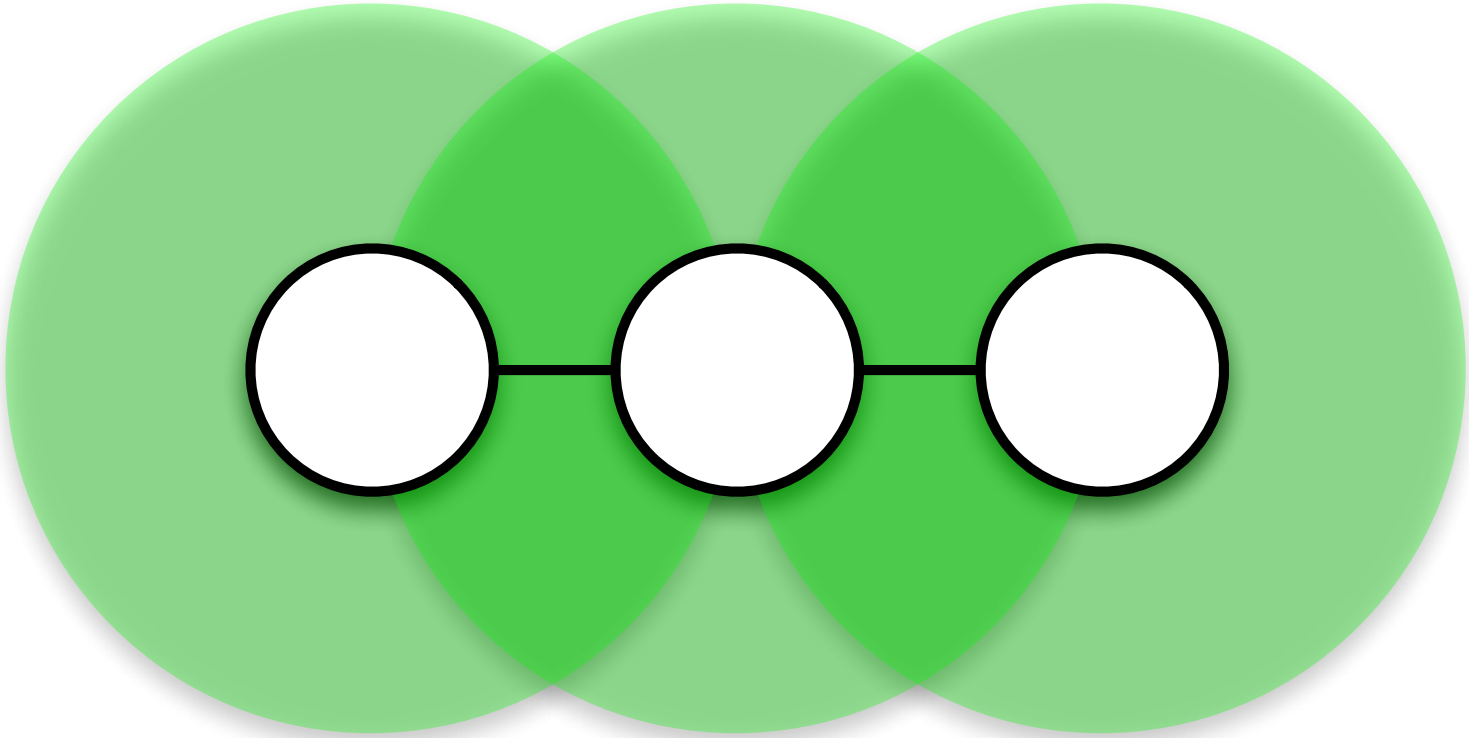
Context & Motivation

Wireless Sensor Networks

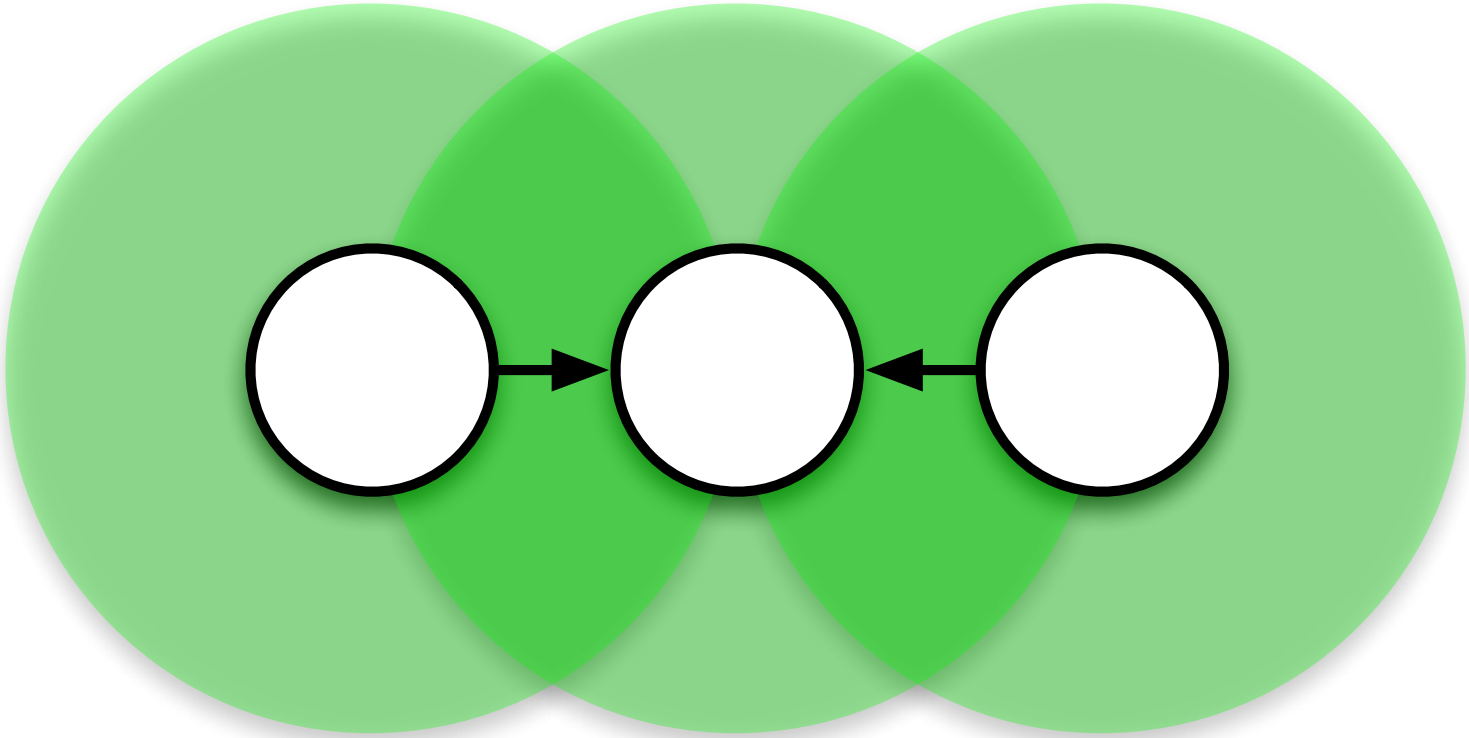
Wireless Sensor Networks



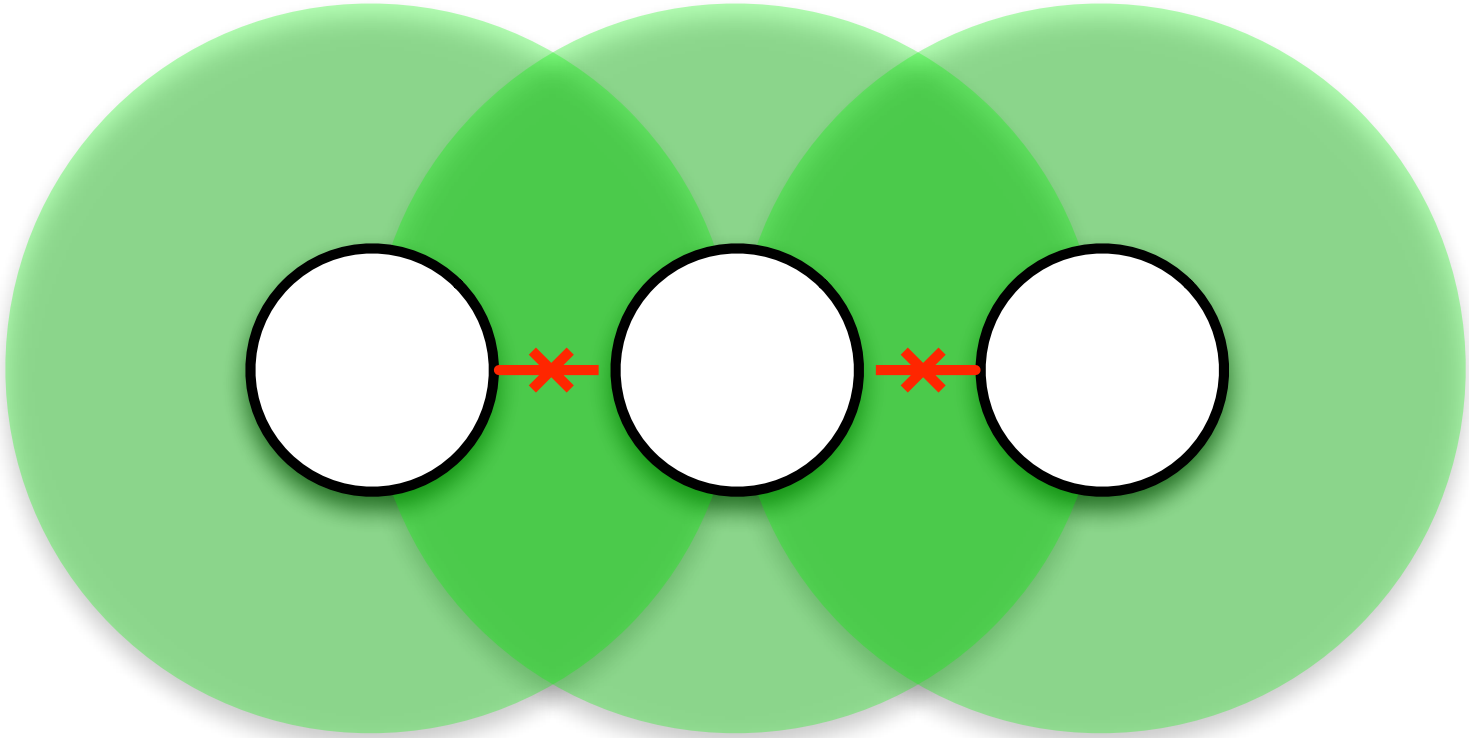
Wireless Sensor Networks



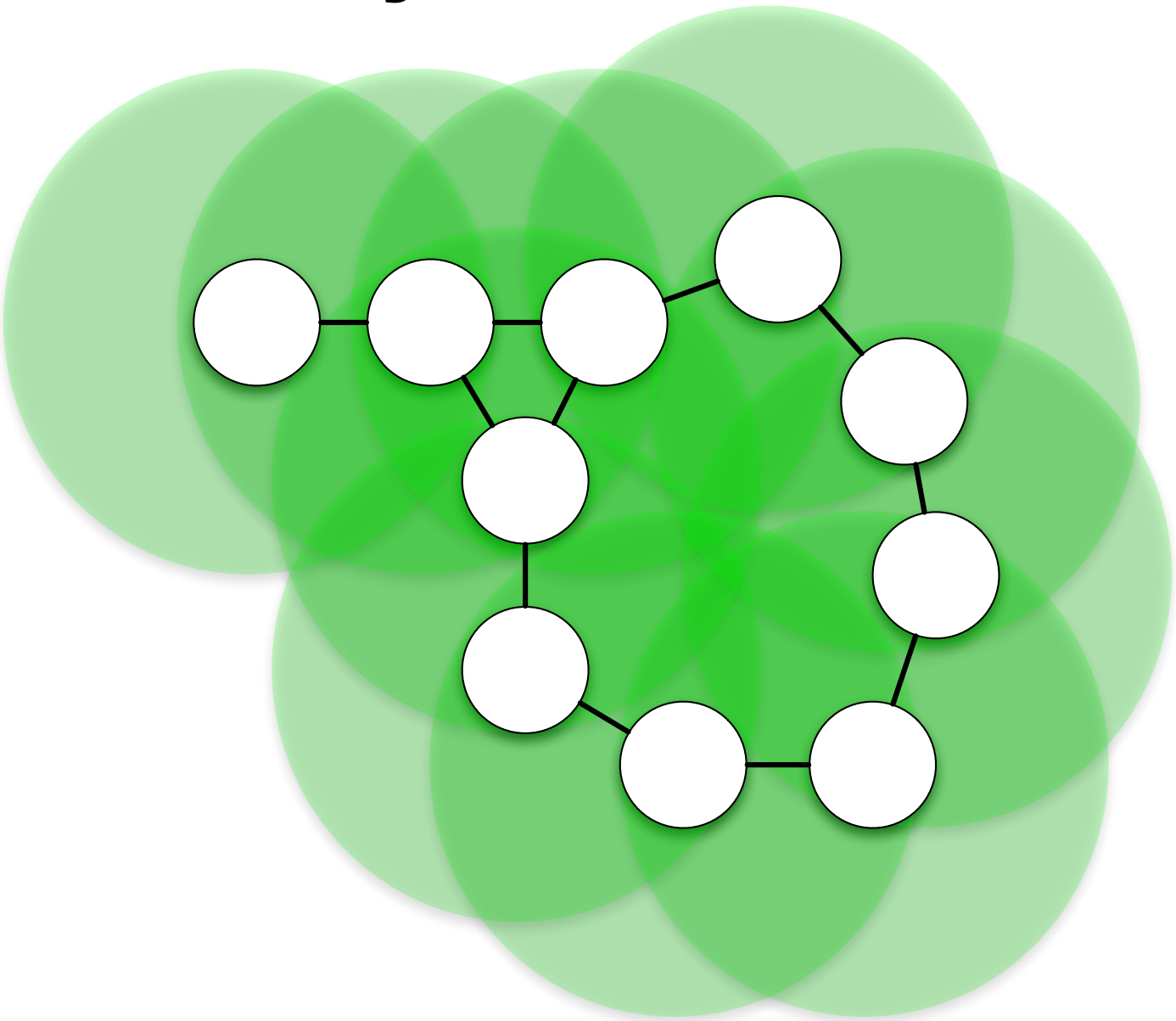
Reliability vs. Redundancy



Reliability vs. Redundancy



Dynamicity vs. Global State



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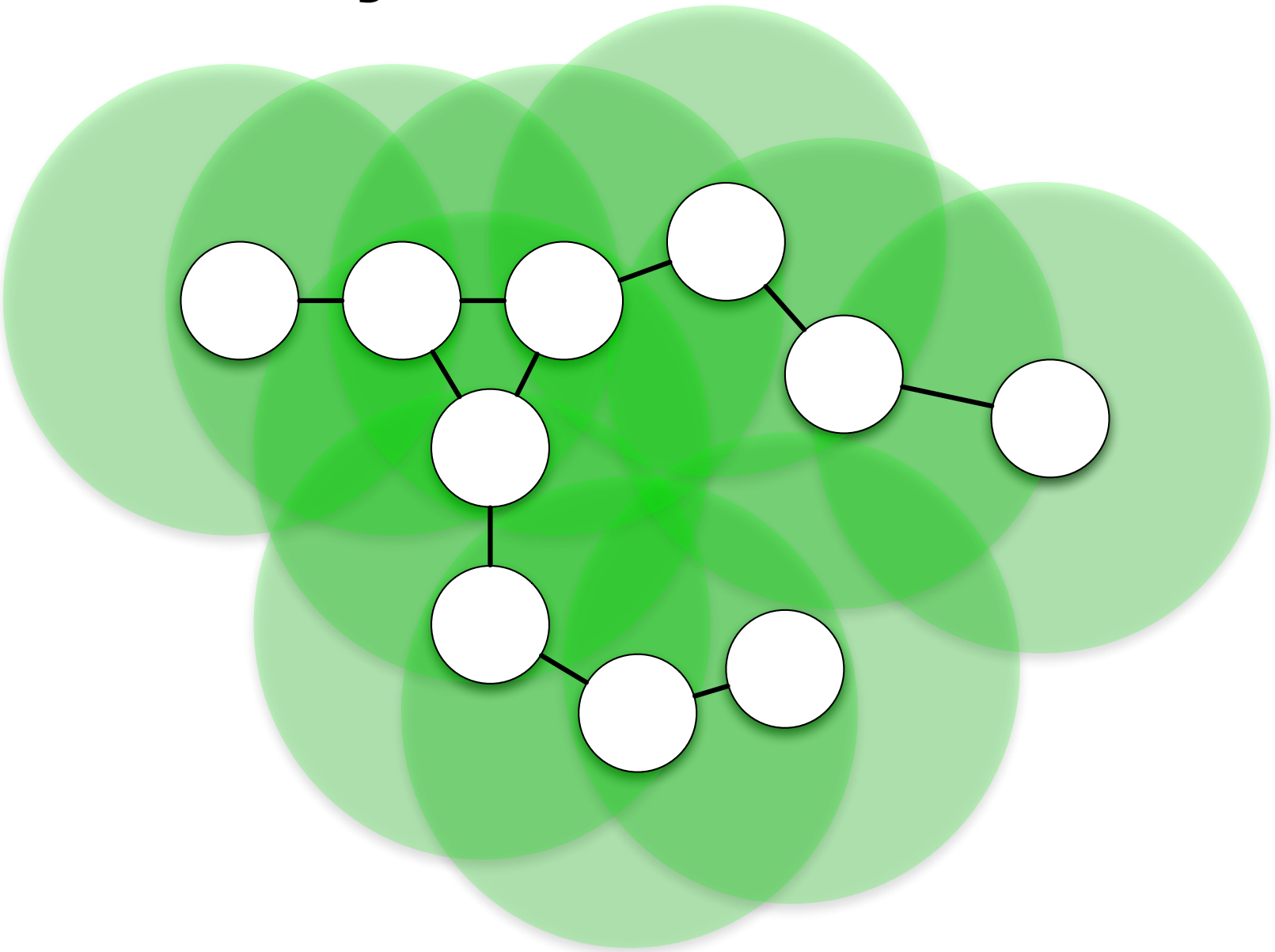

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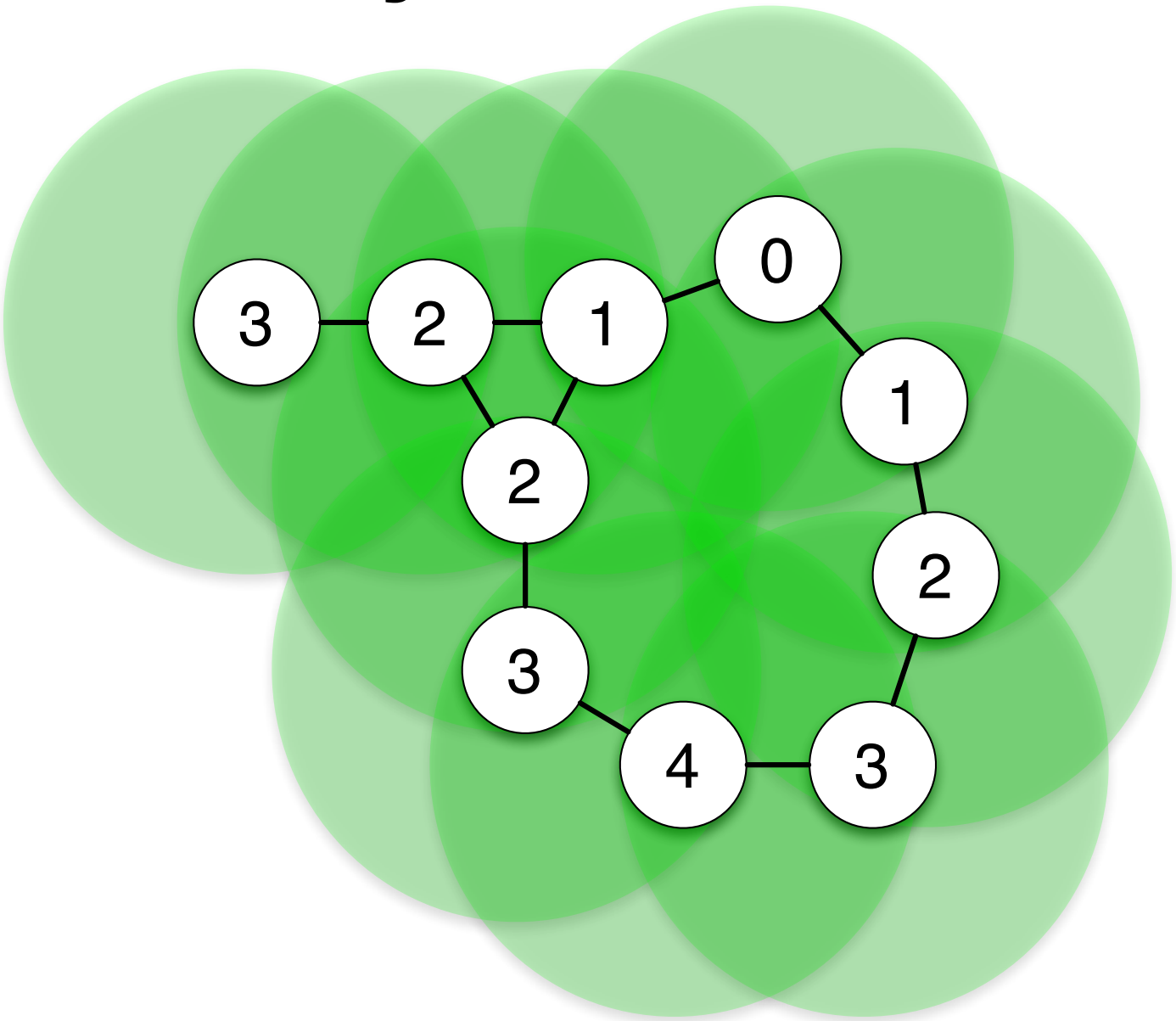

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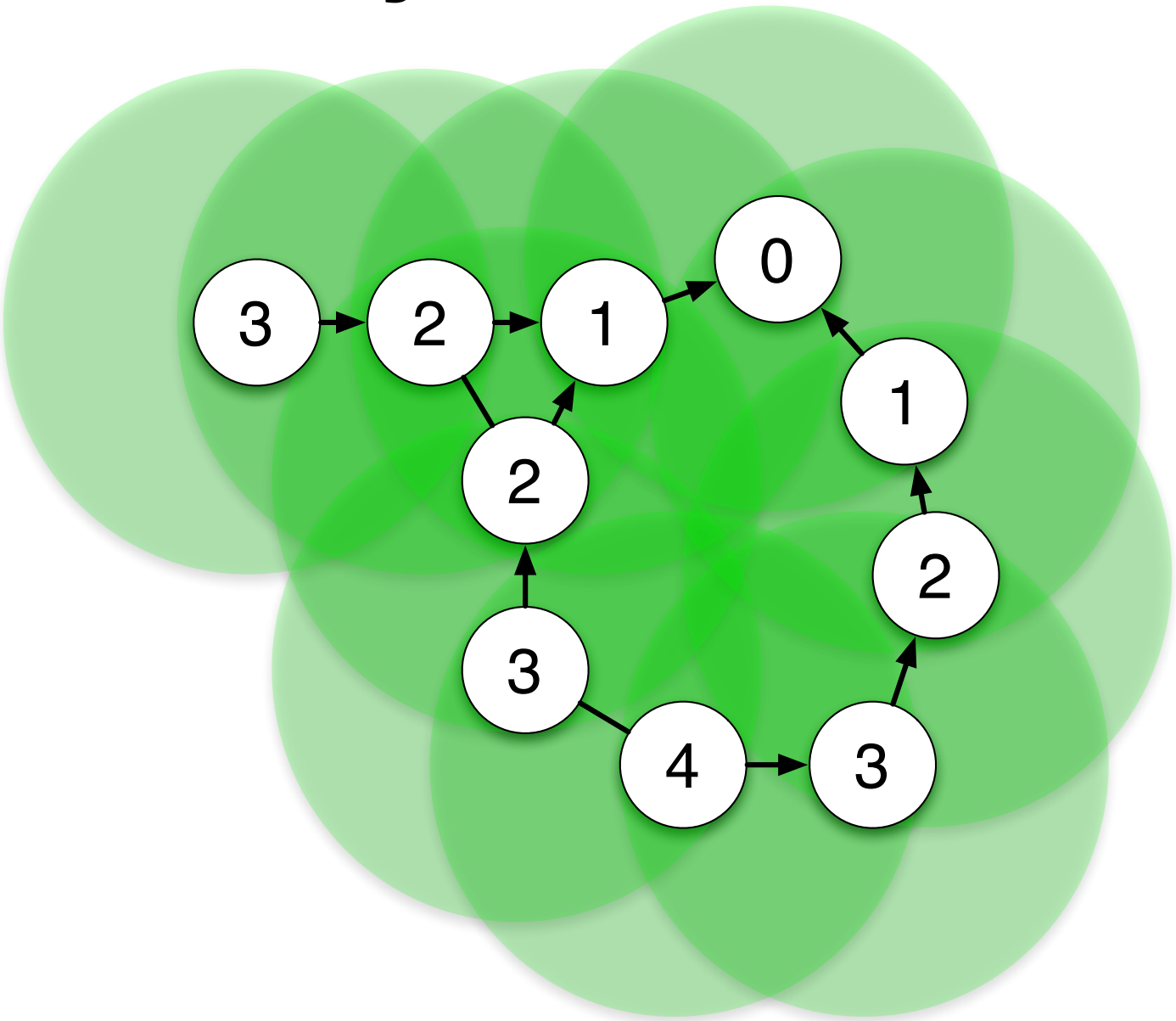
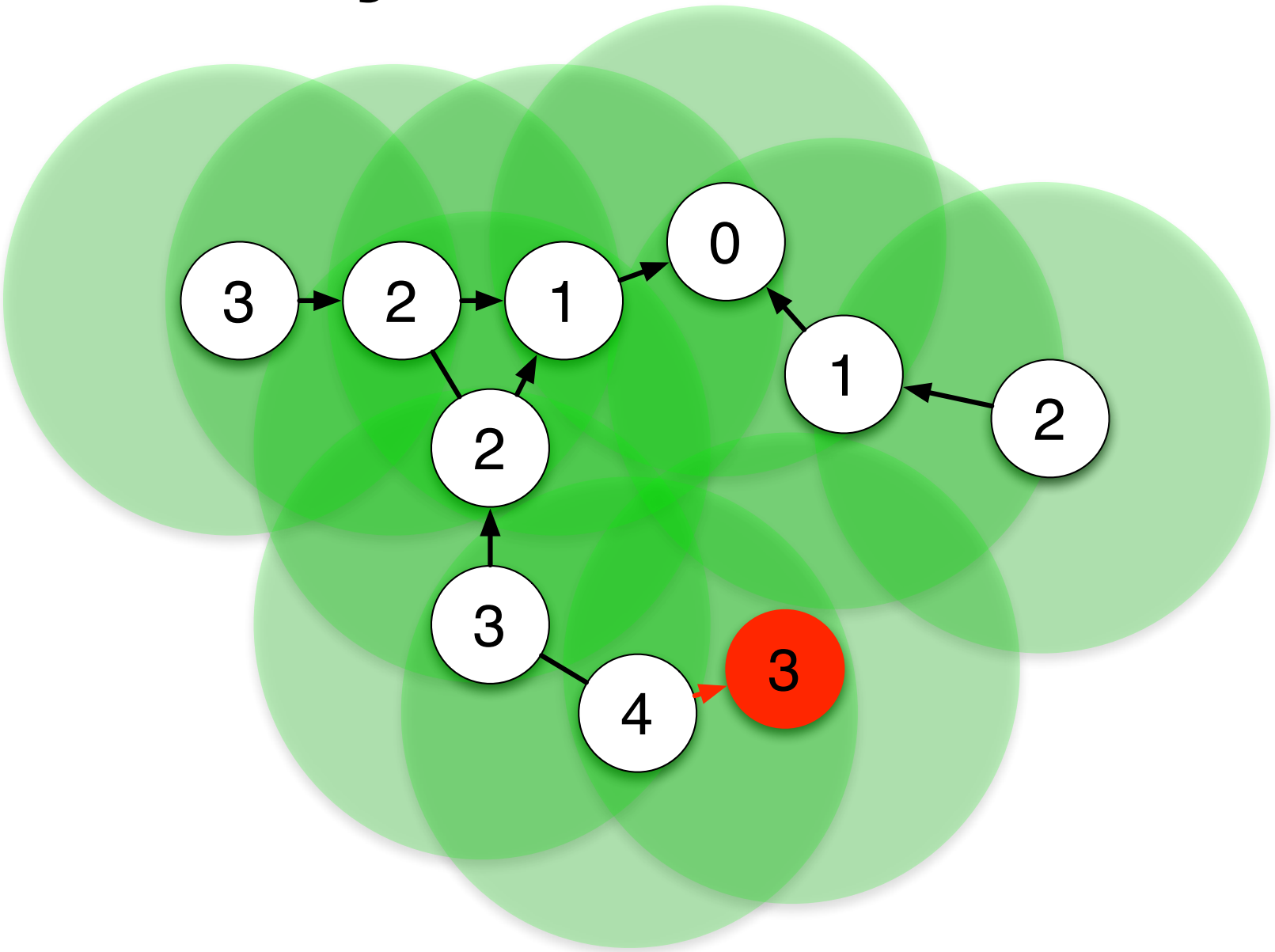


Dynamicity vs. Global State



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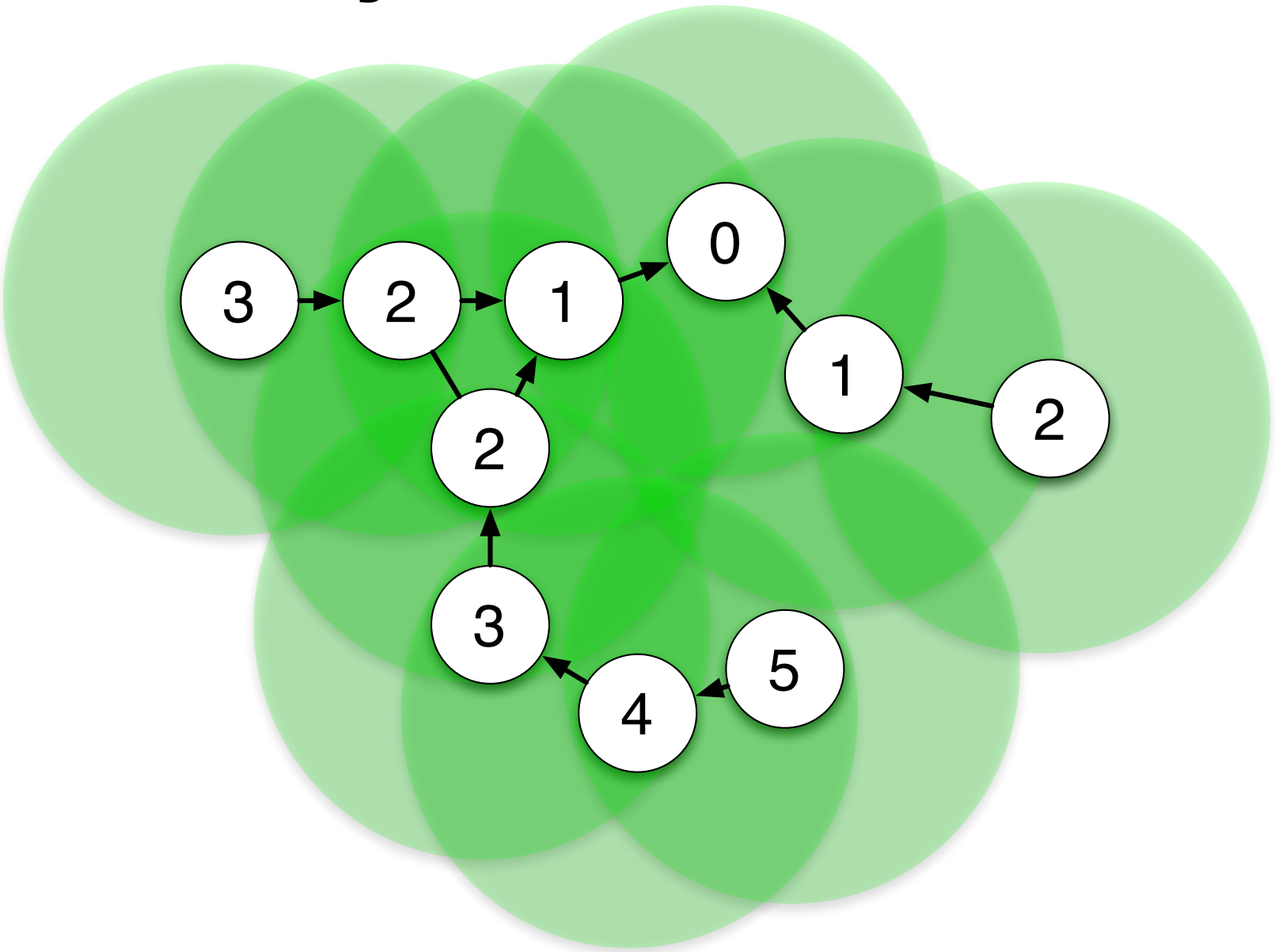
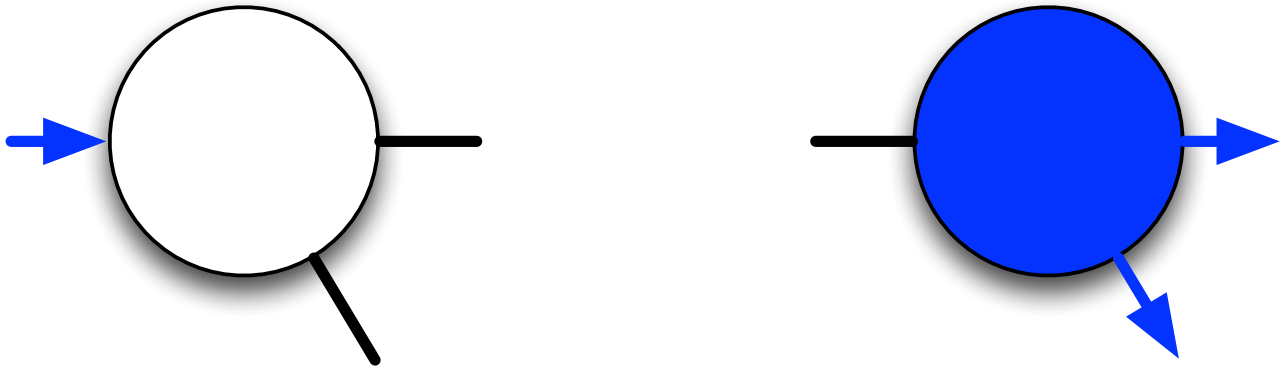


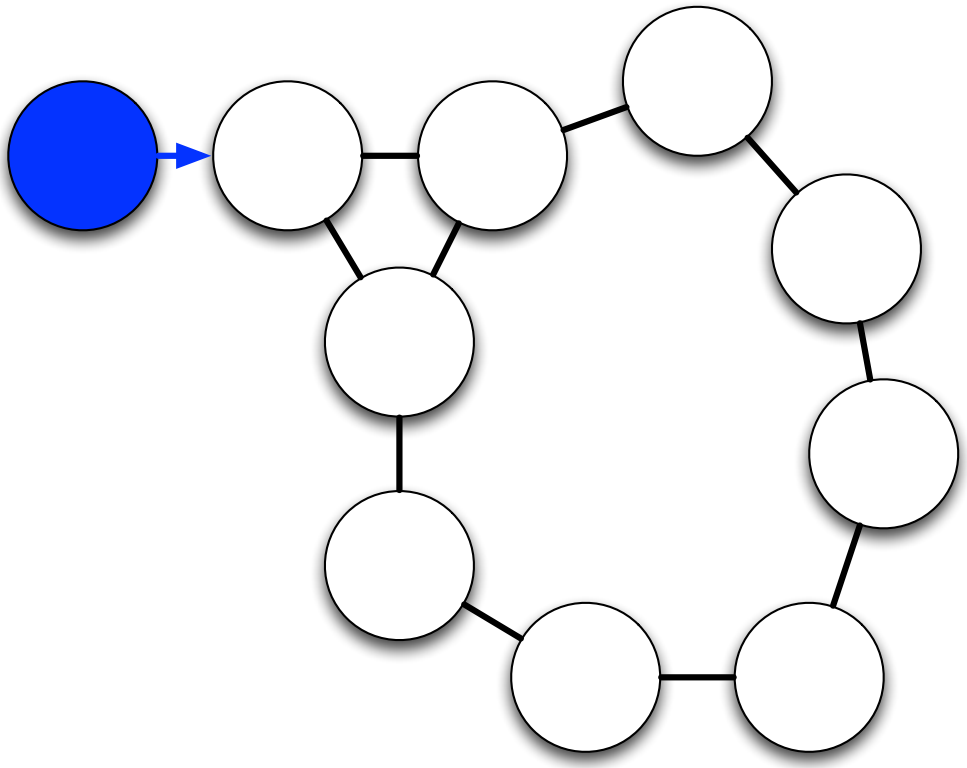
Stateless Routing

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

Flooding



Stateful Flooding



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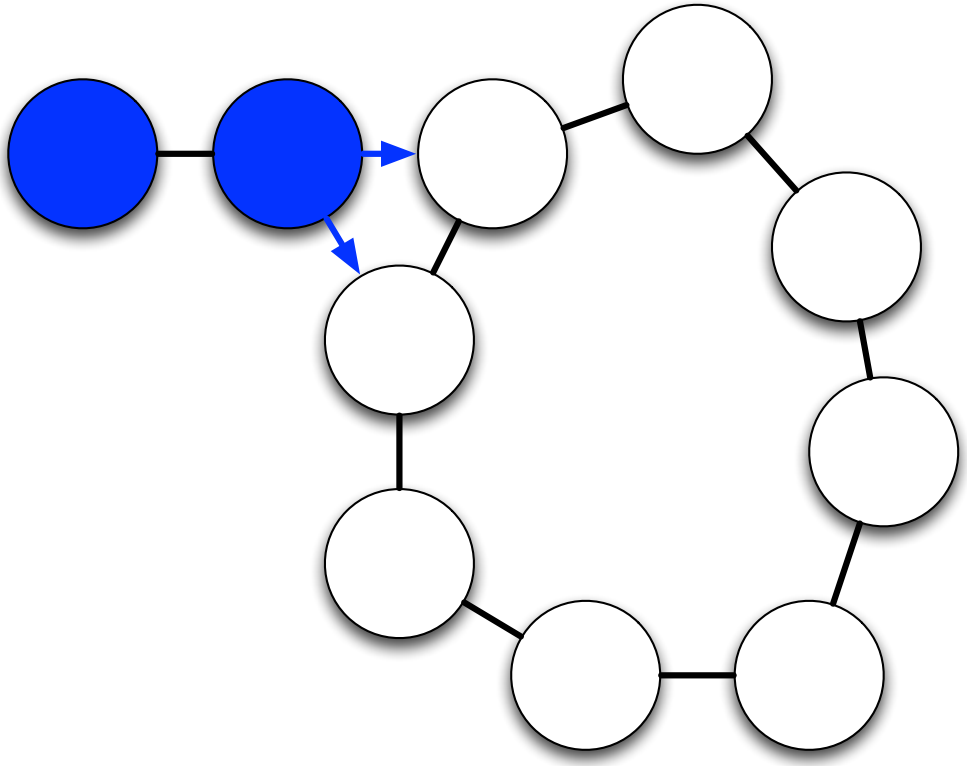

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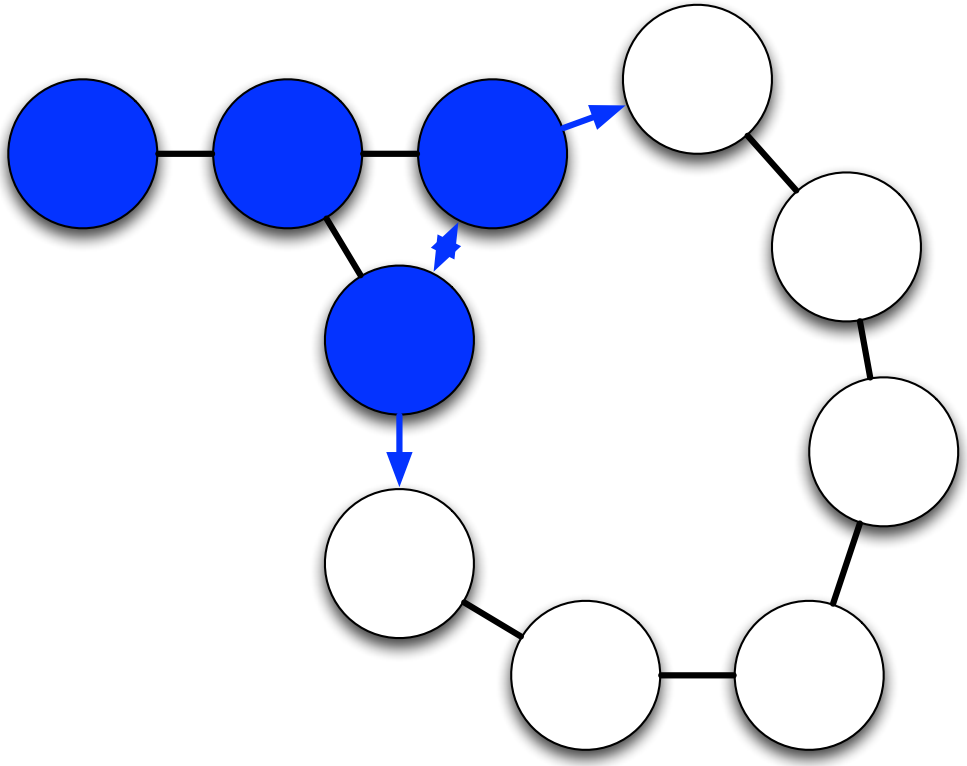

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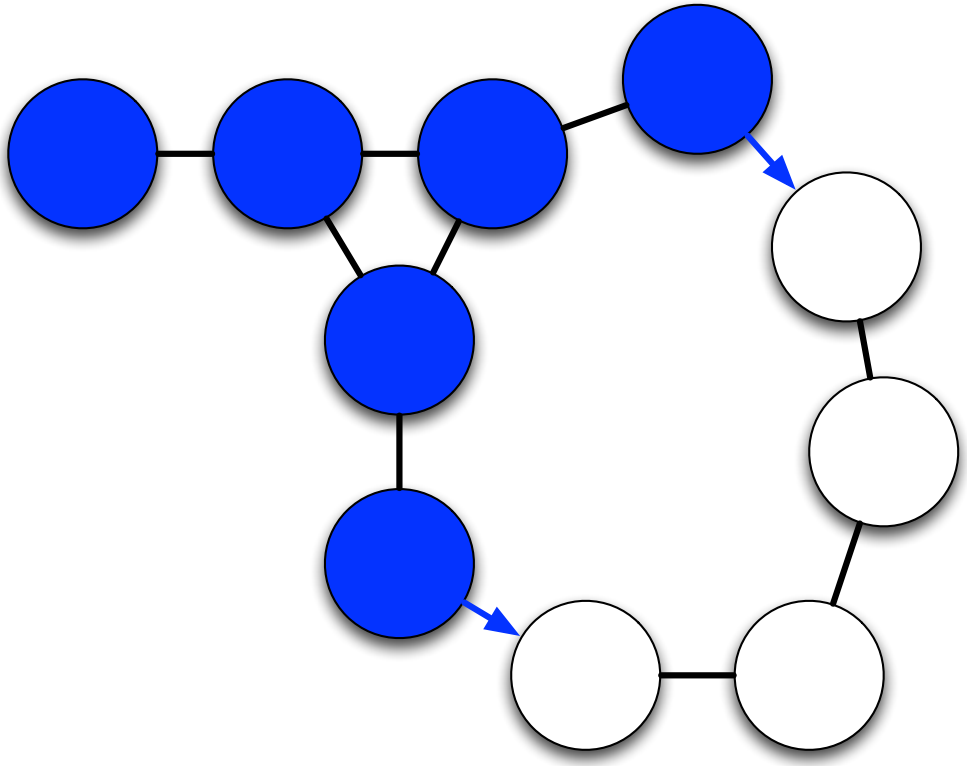

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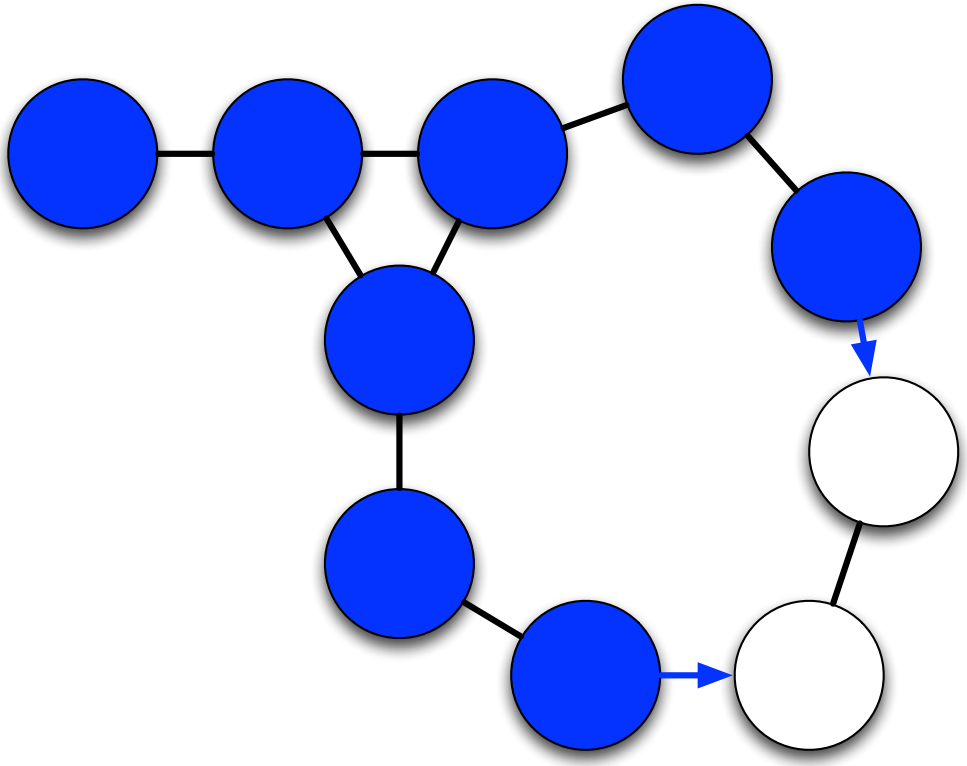

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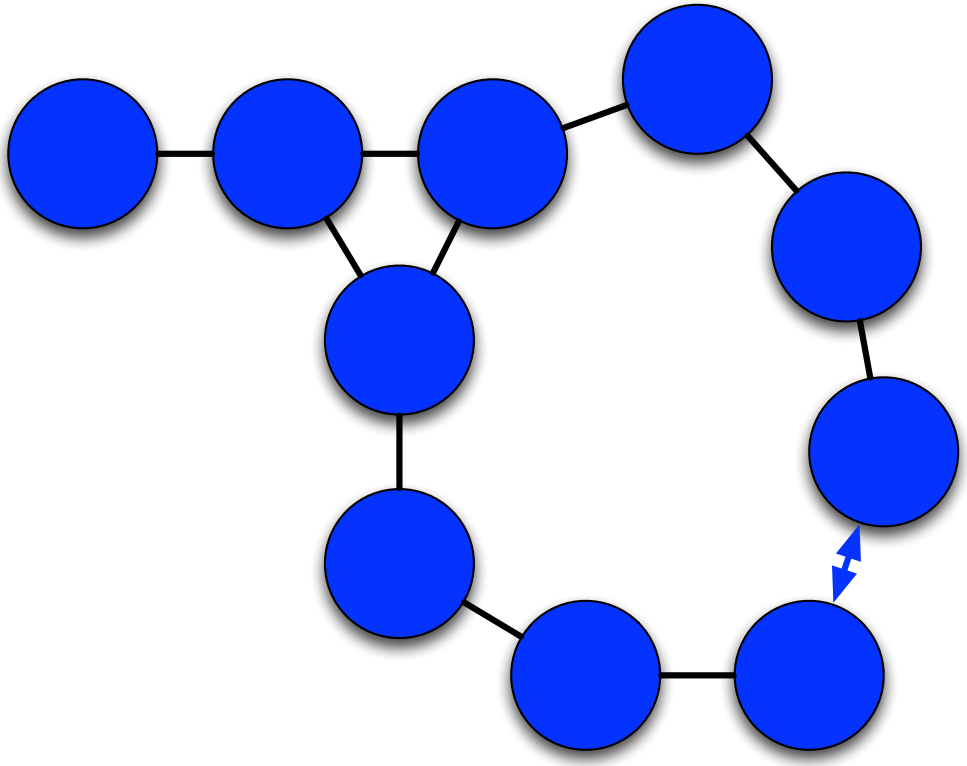

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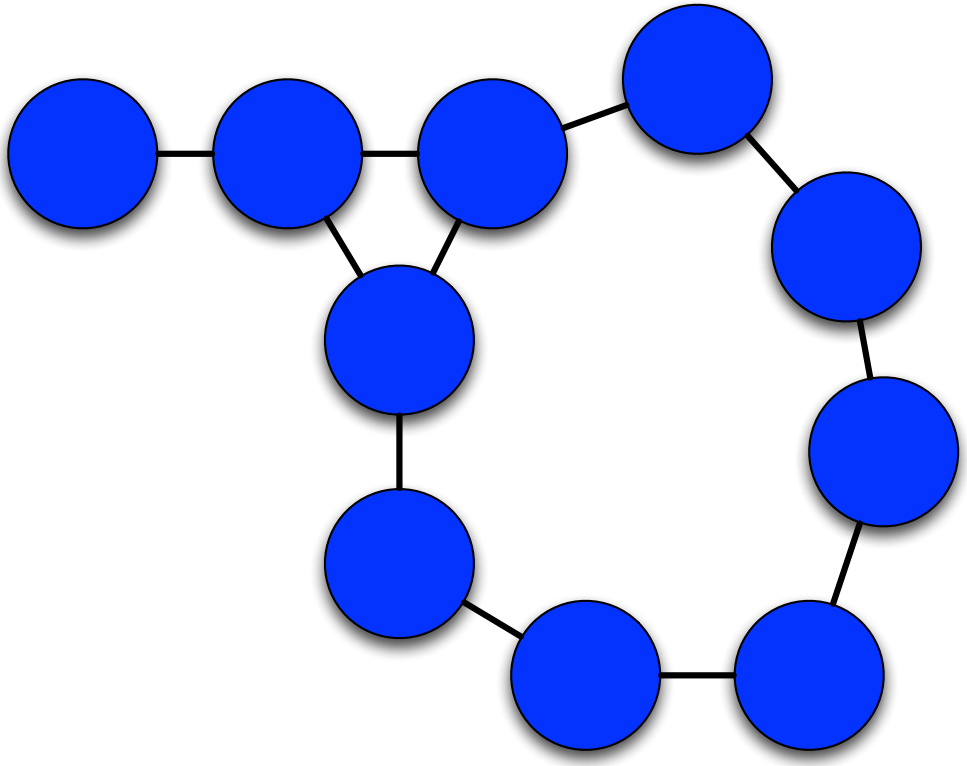

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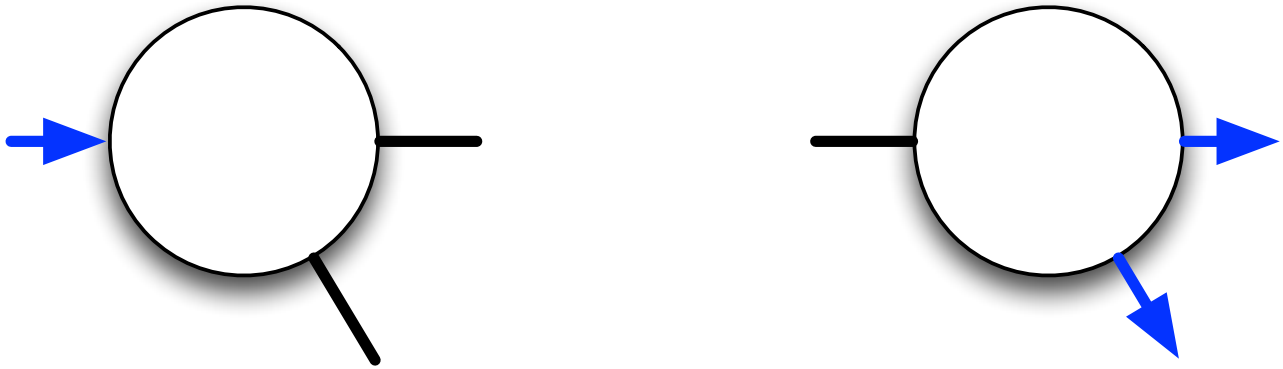

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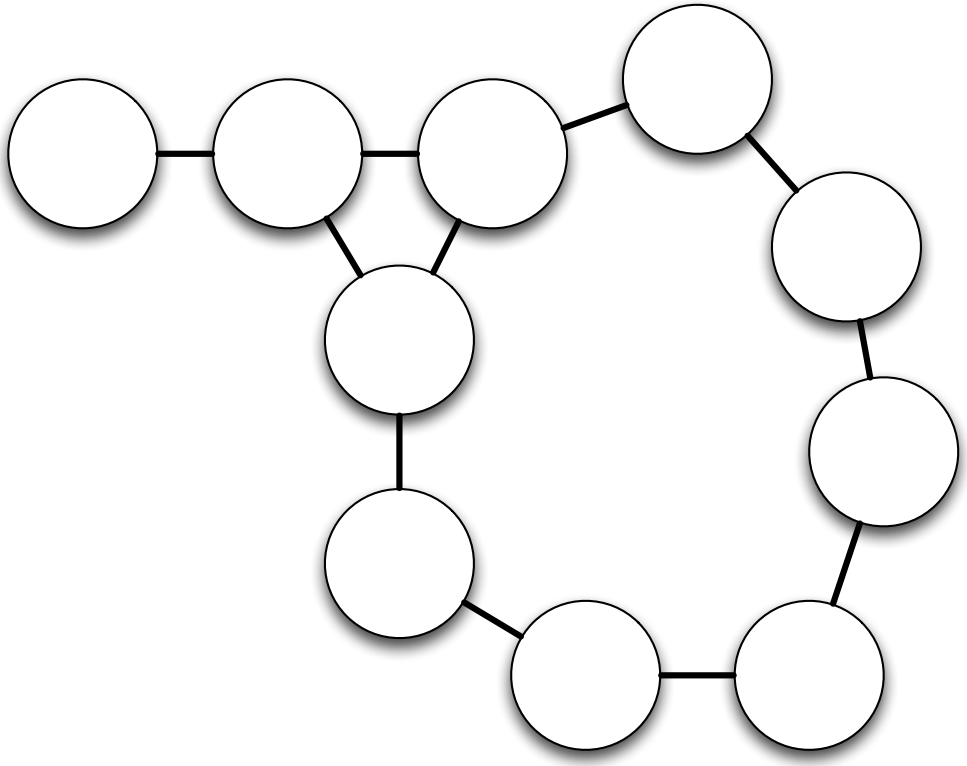

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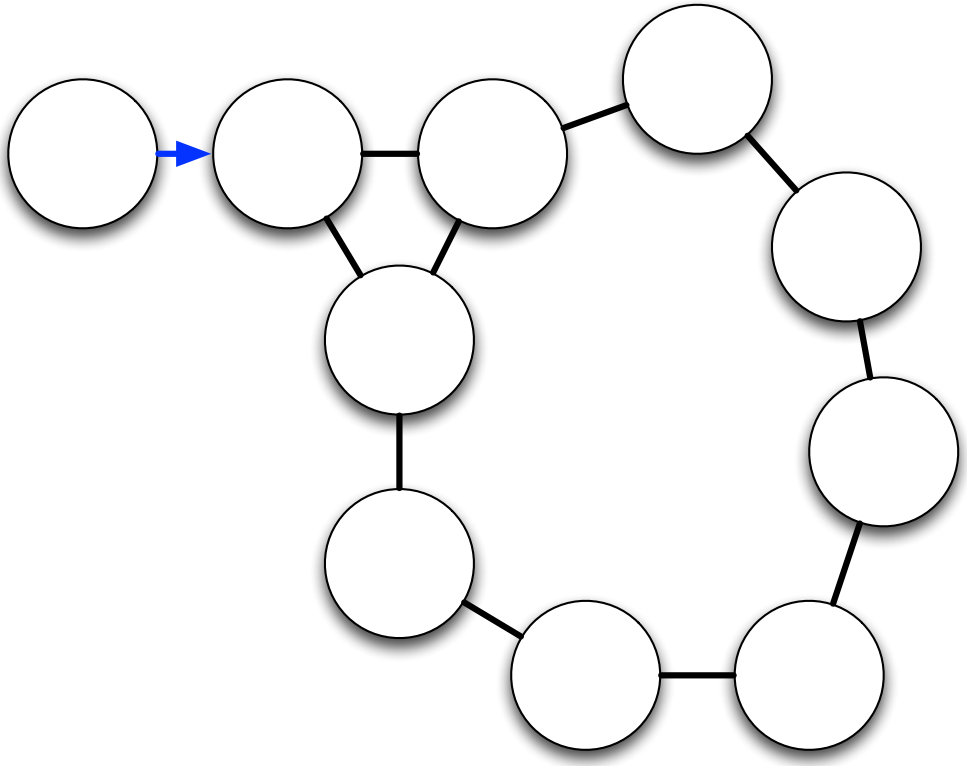

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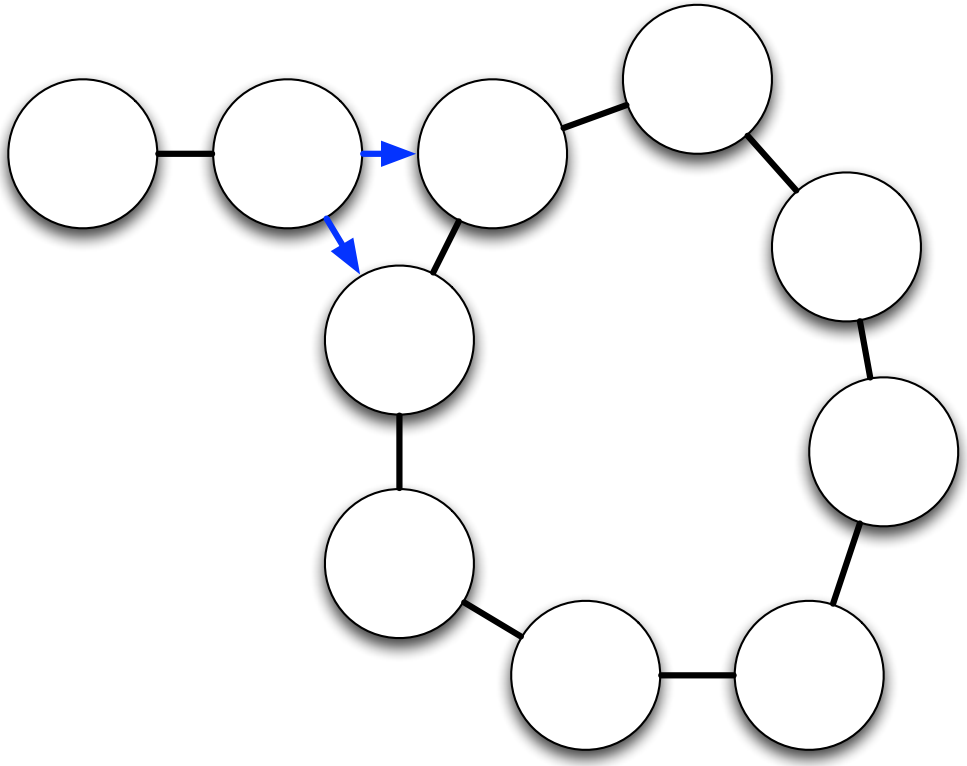

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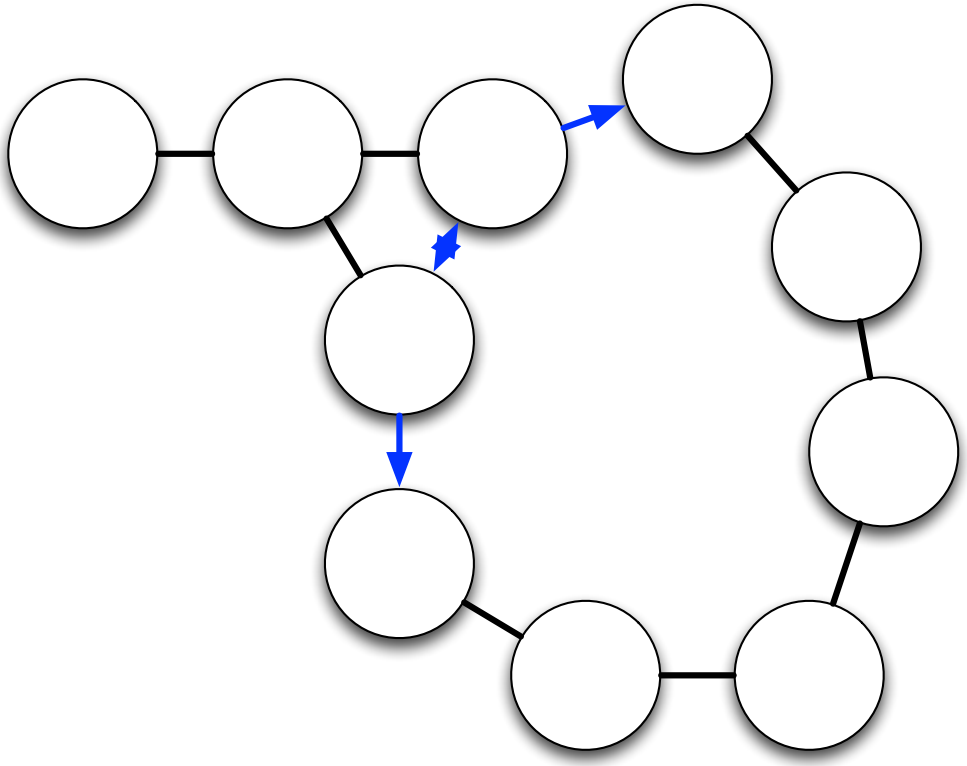

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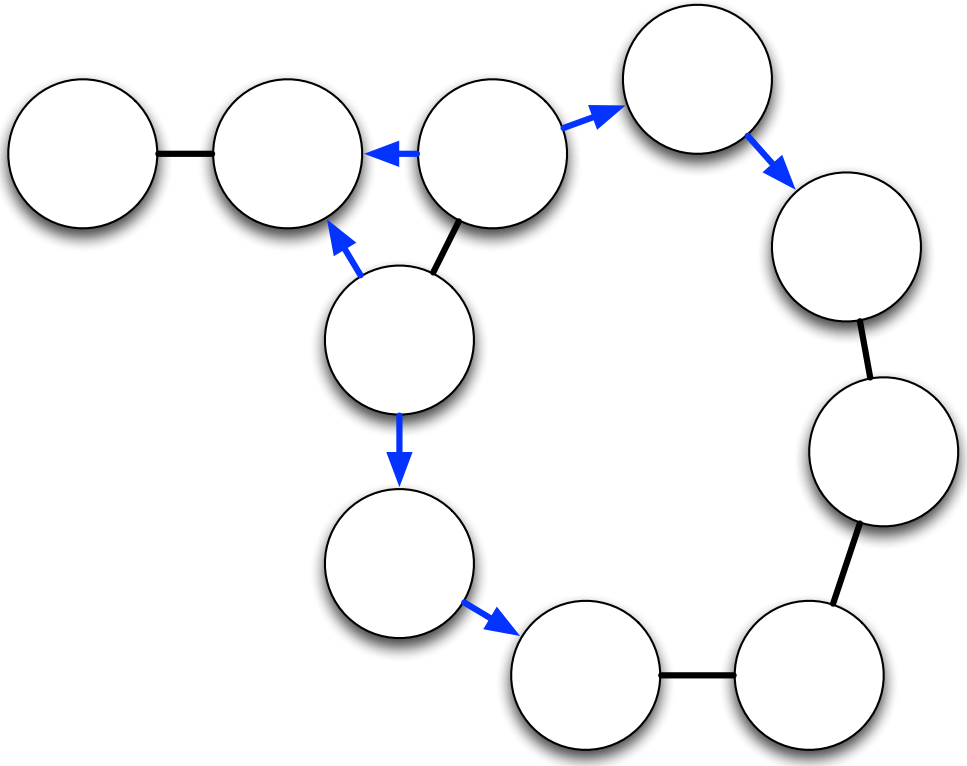

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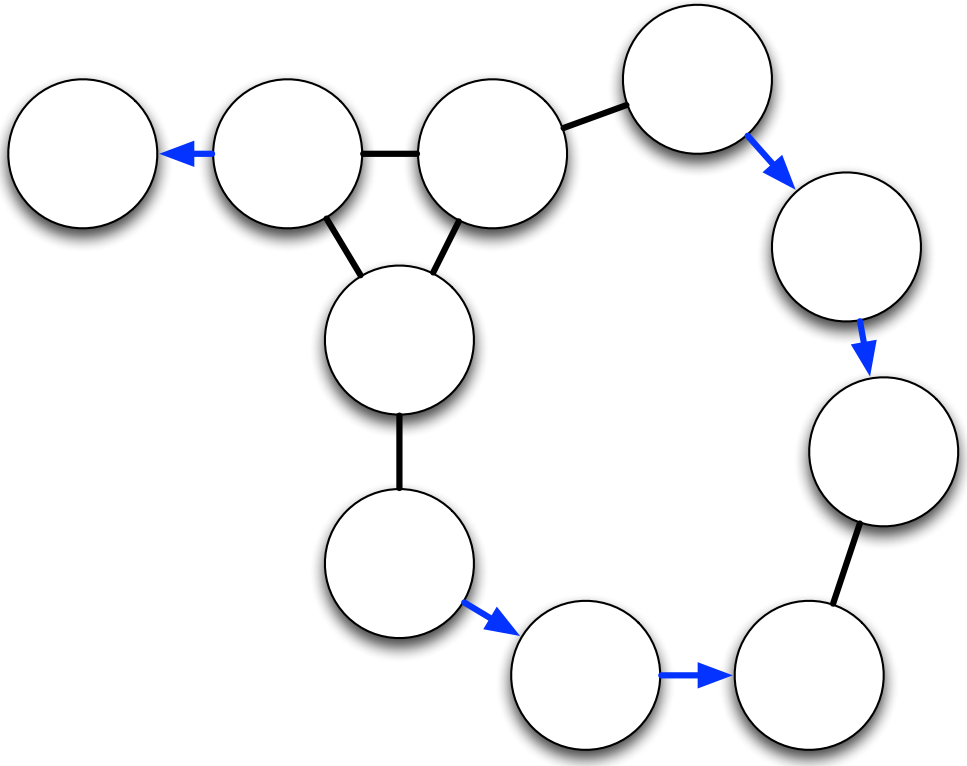

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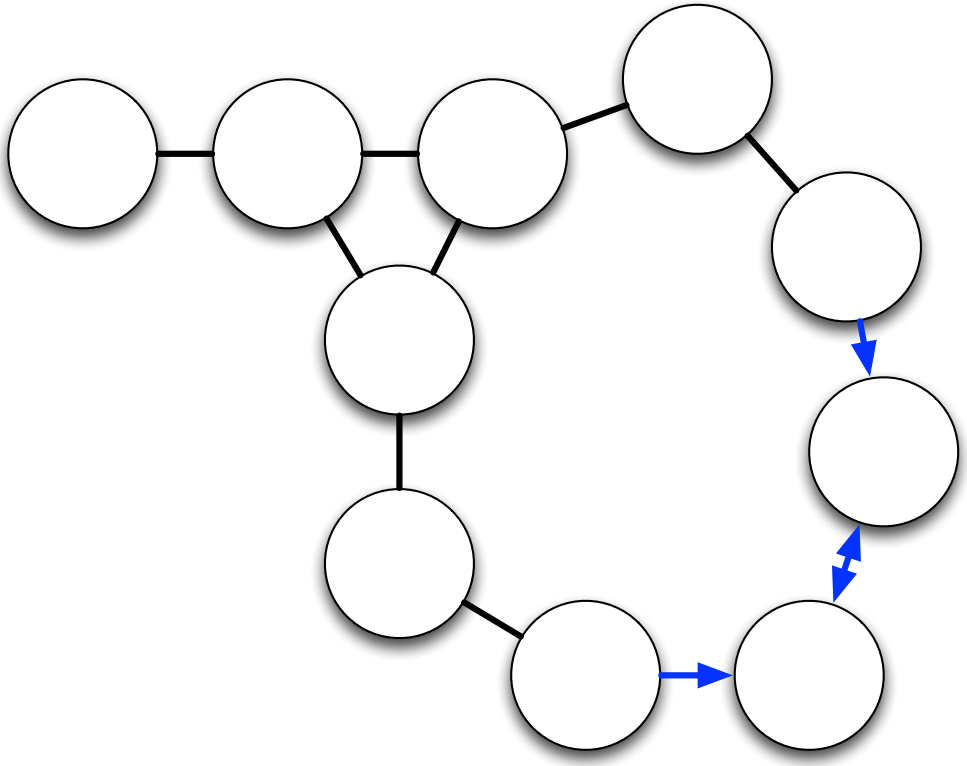

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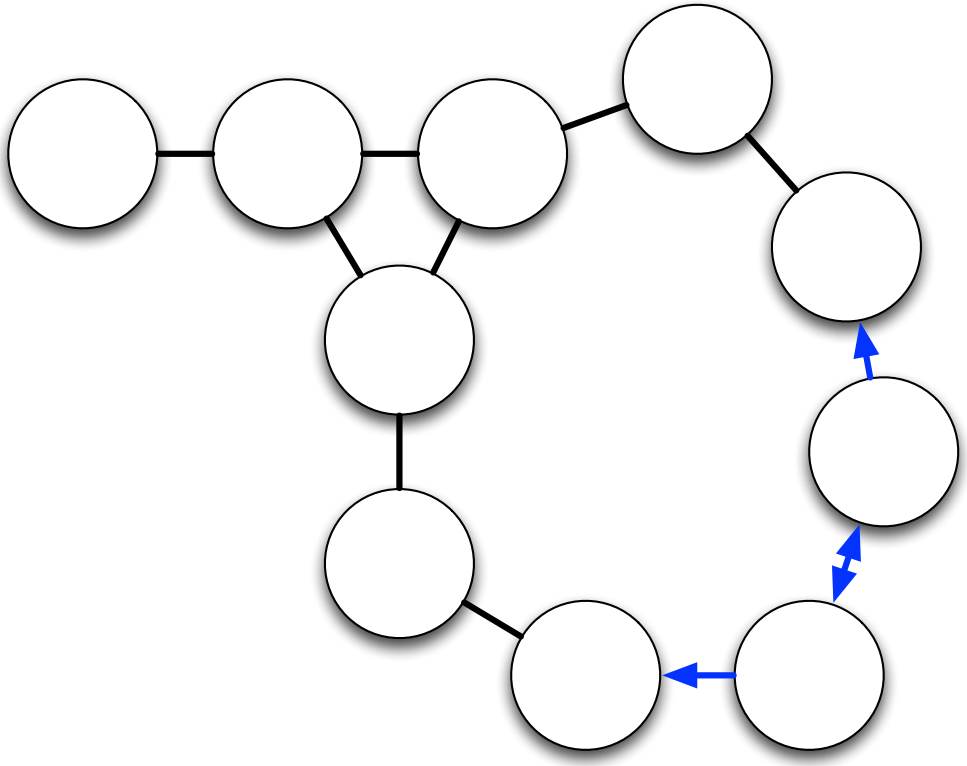

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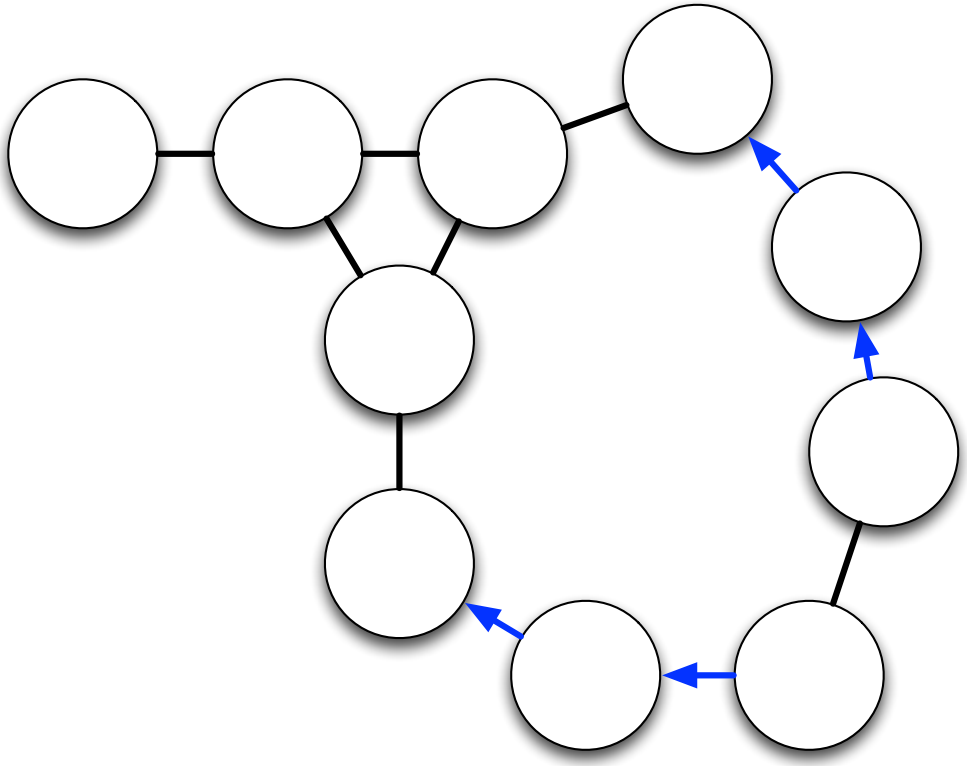

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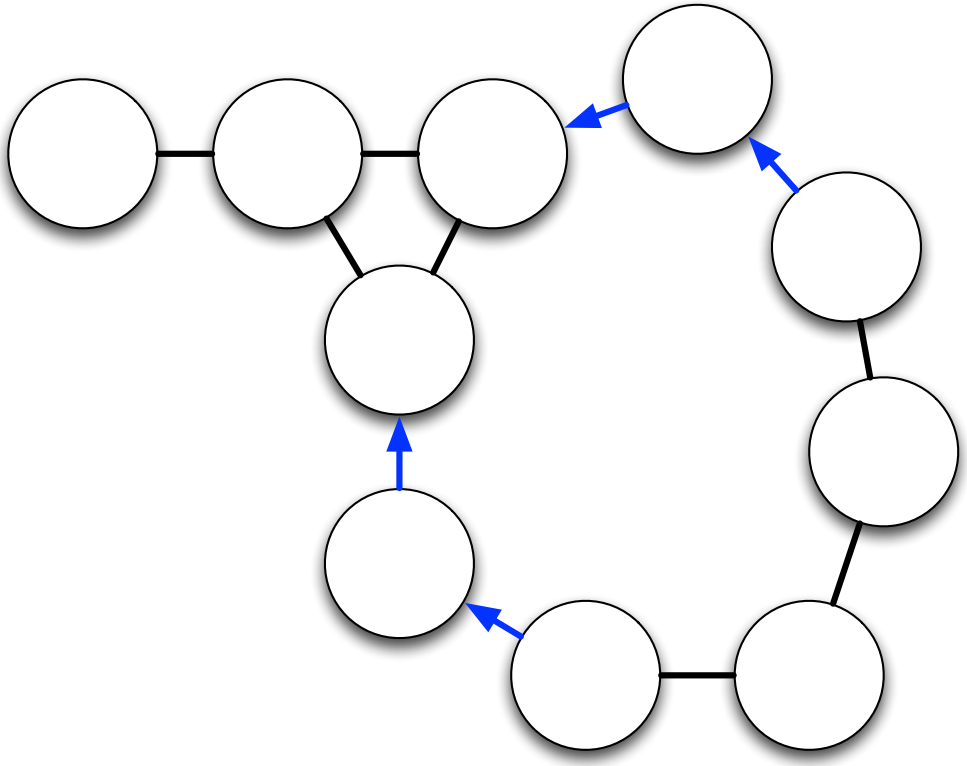

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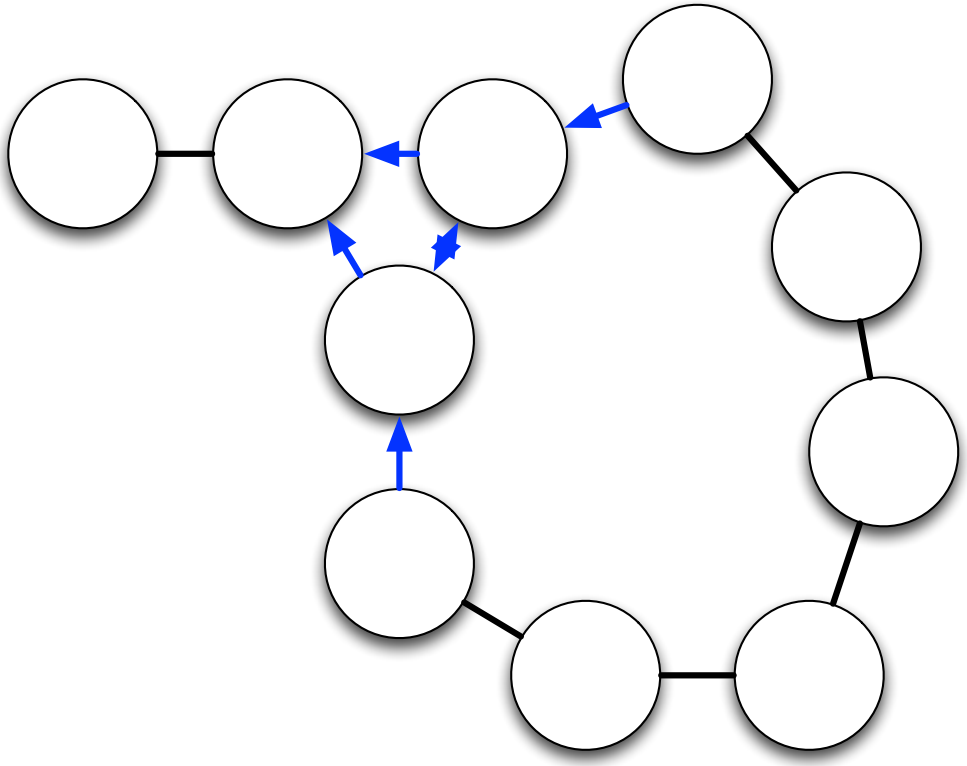

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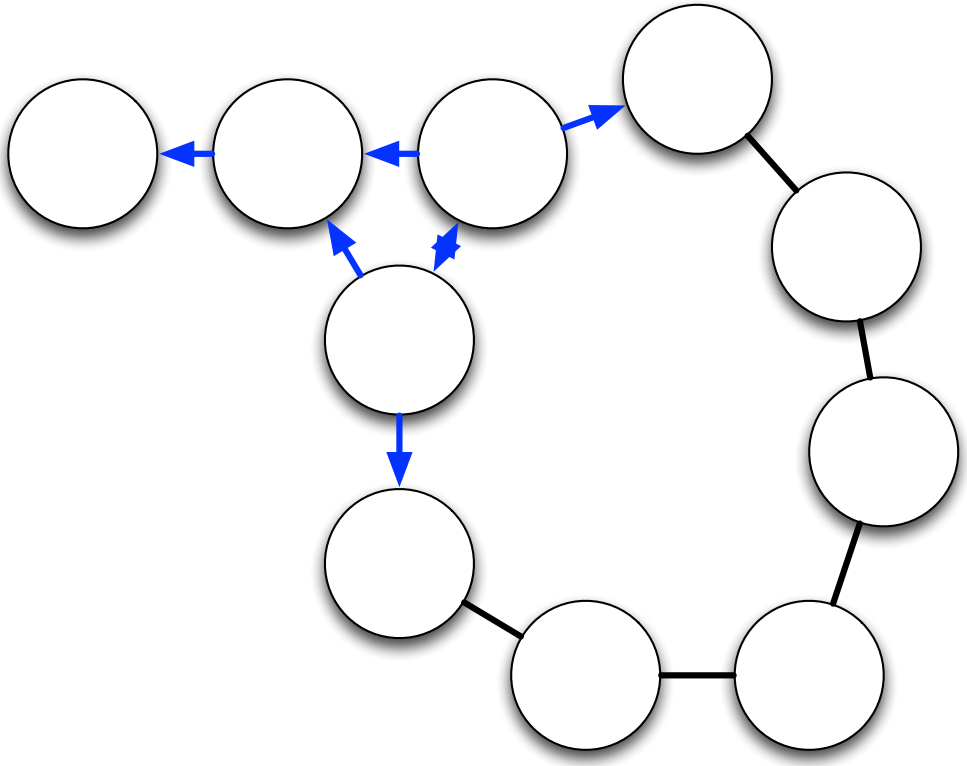

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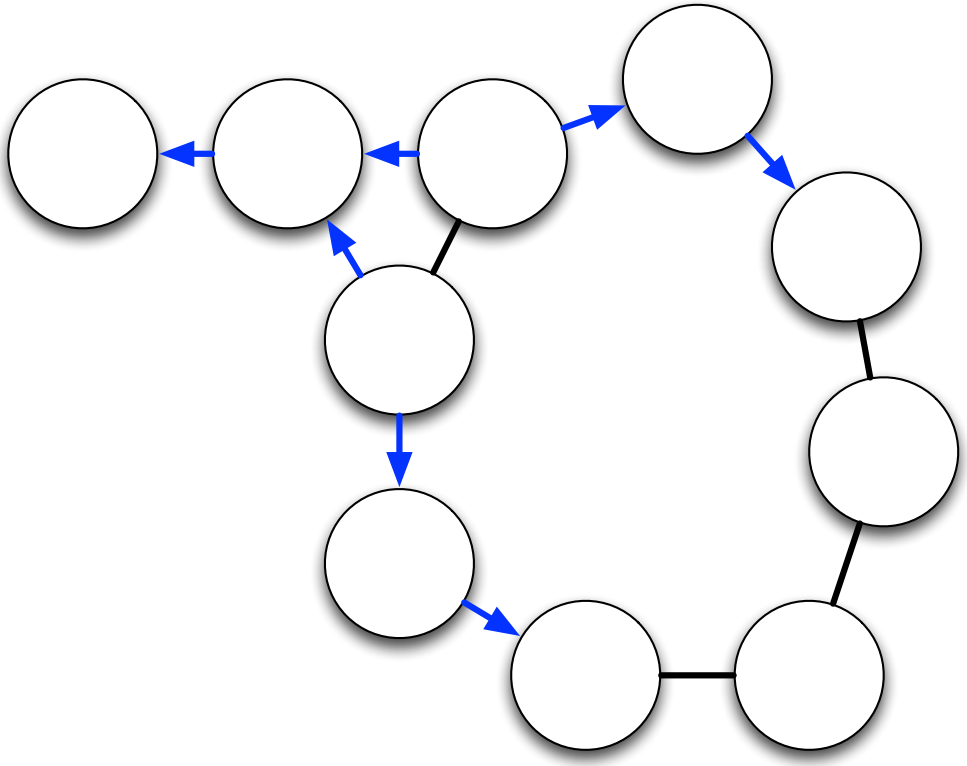

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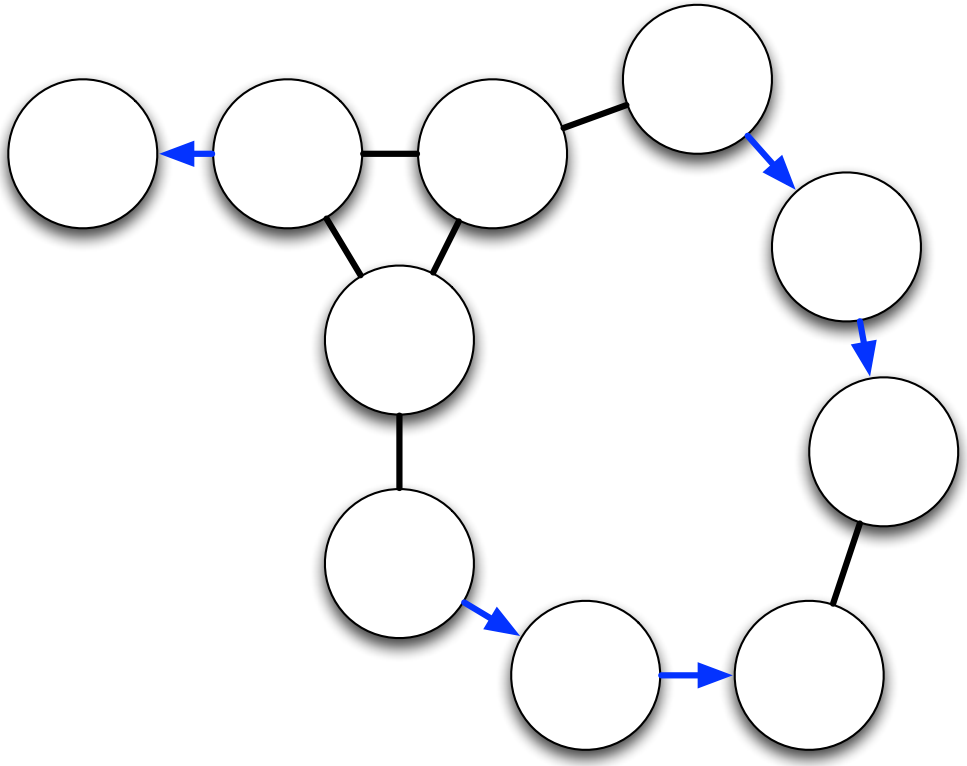
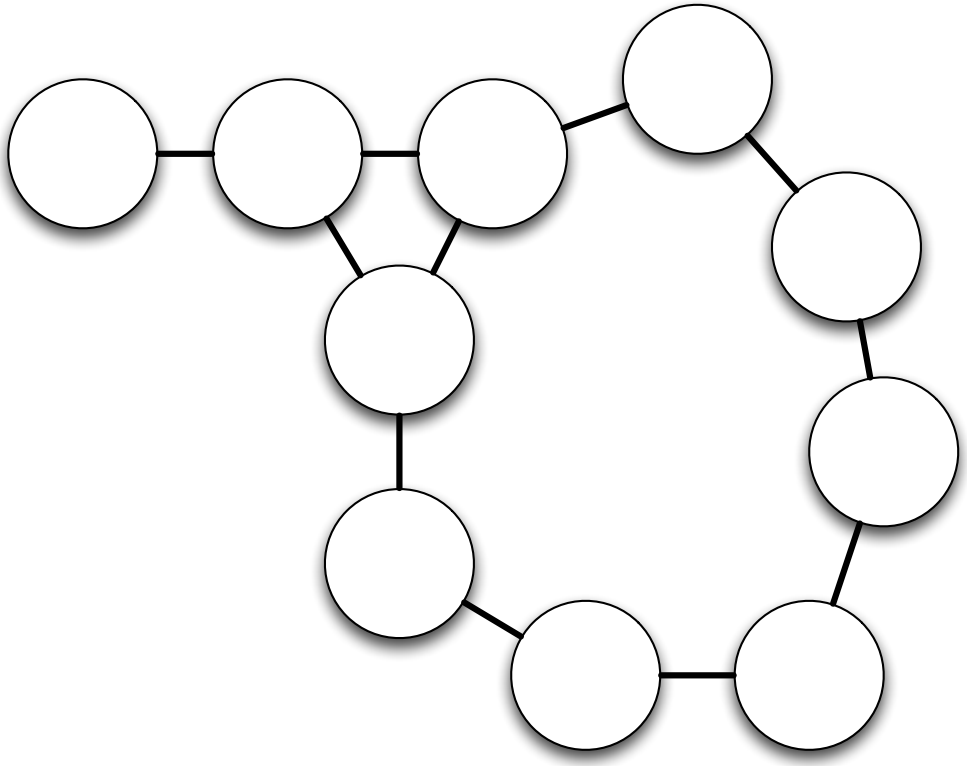


Stateless Flooding v2

TTL Flooding



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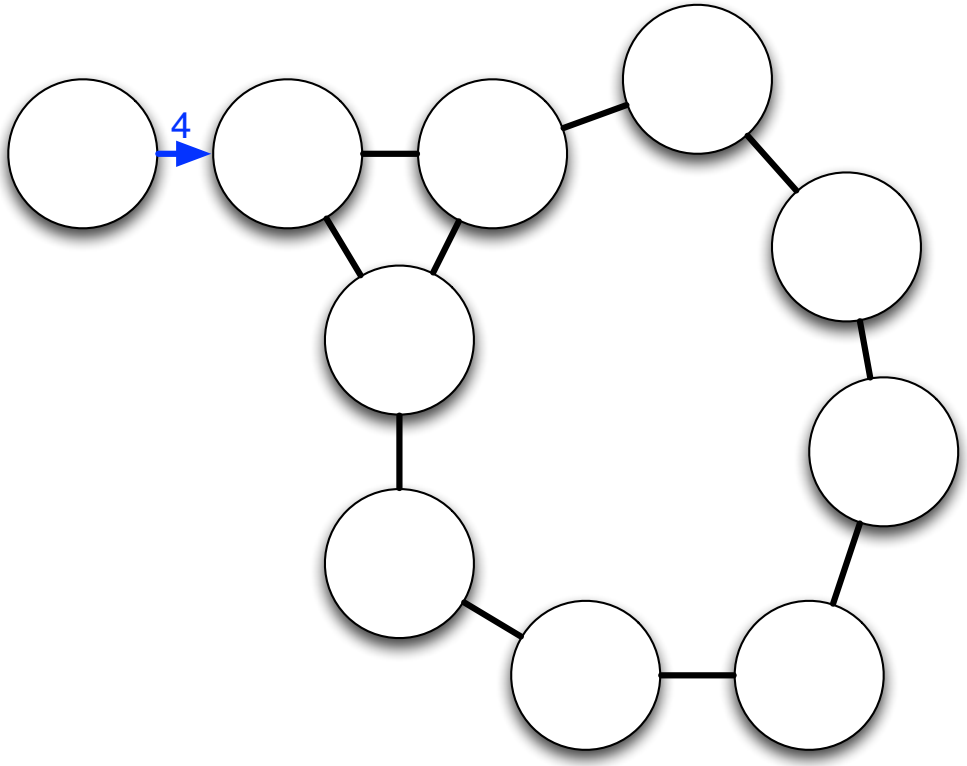

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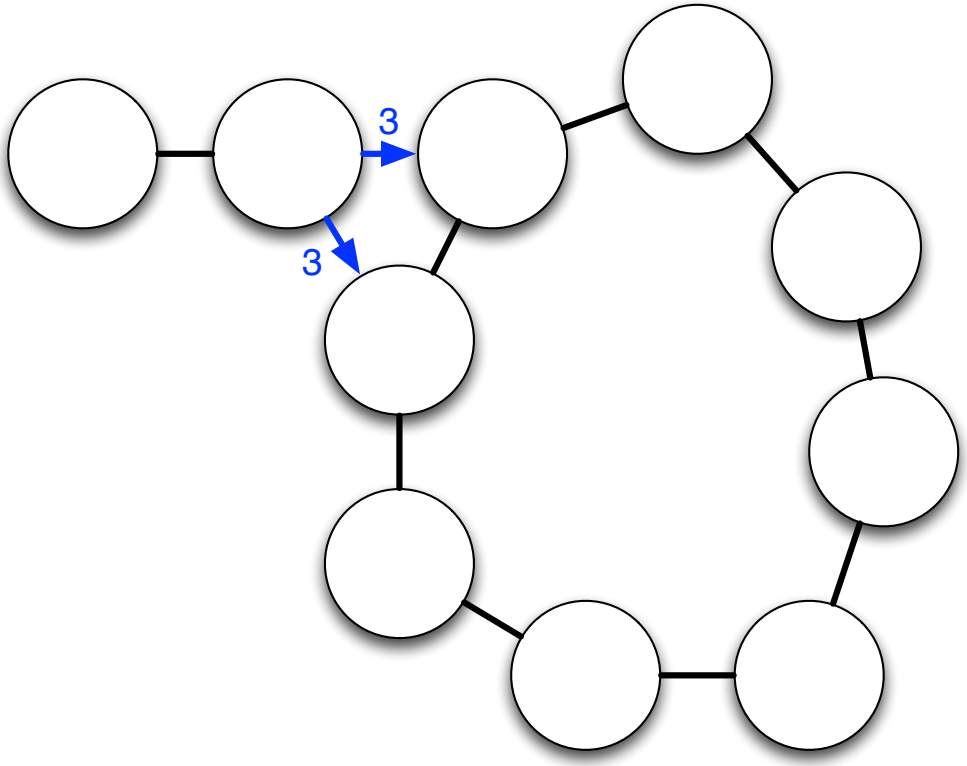

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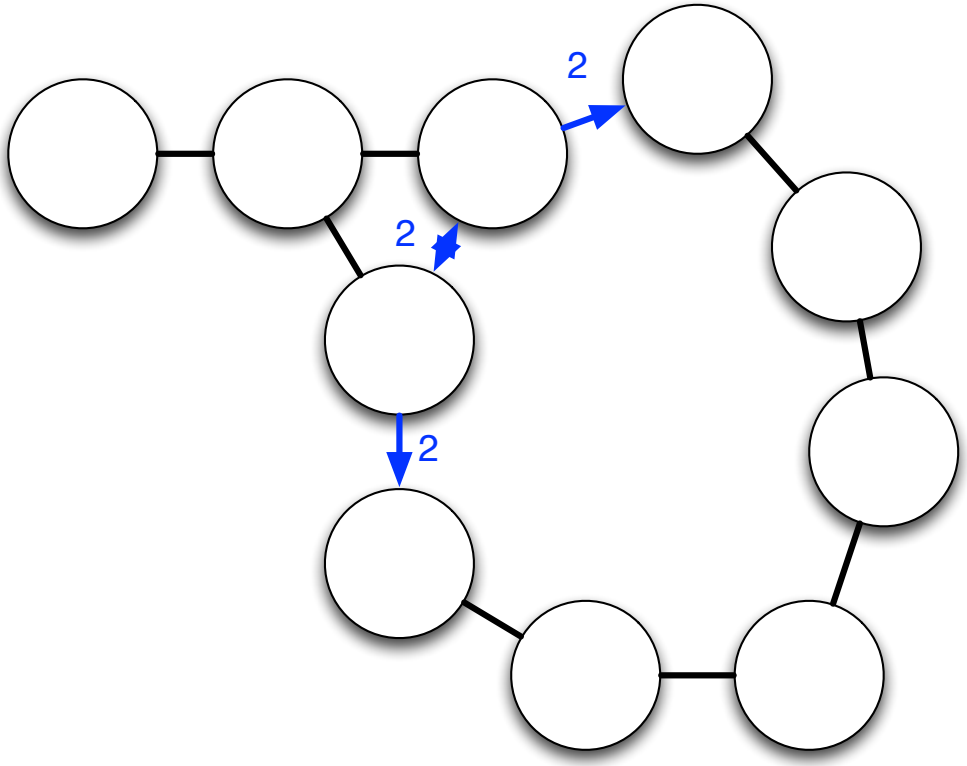

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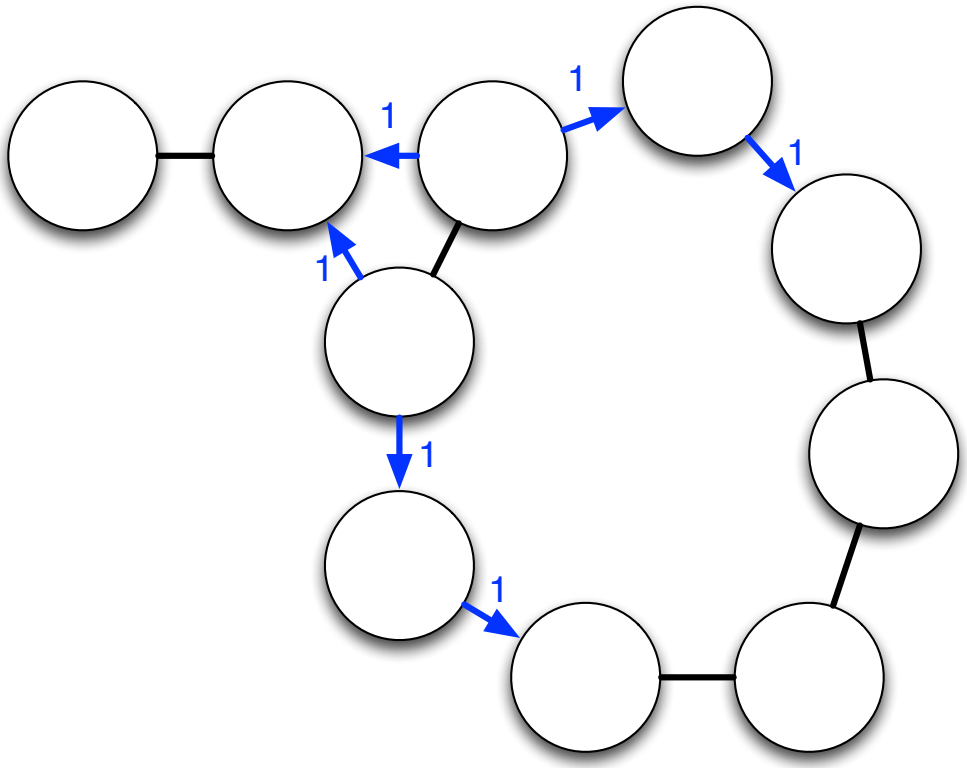

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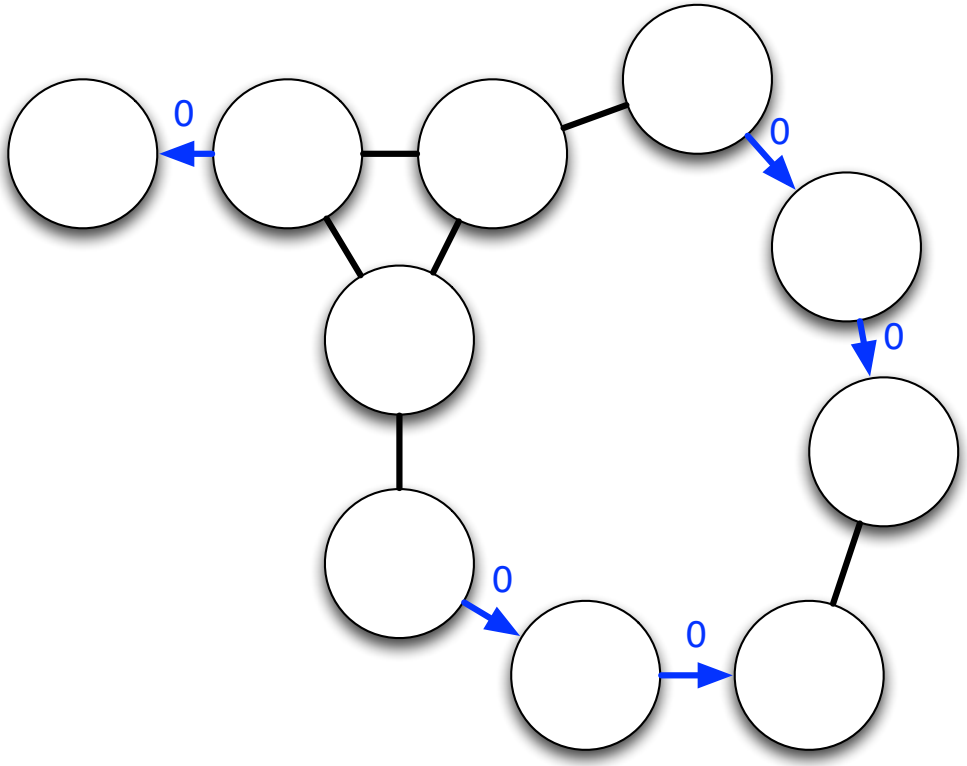

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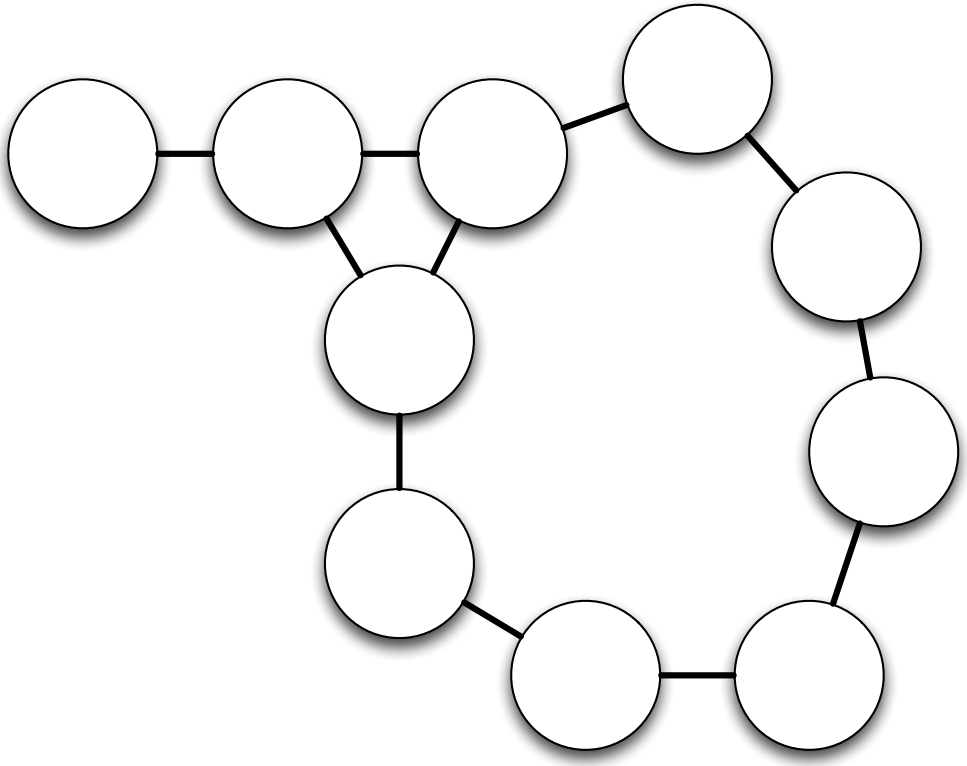
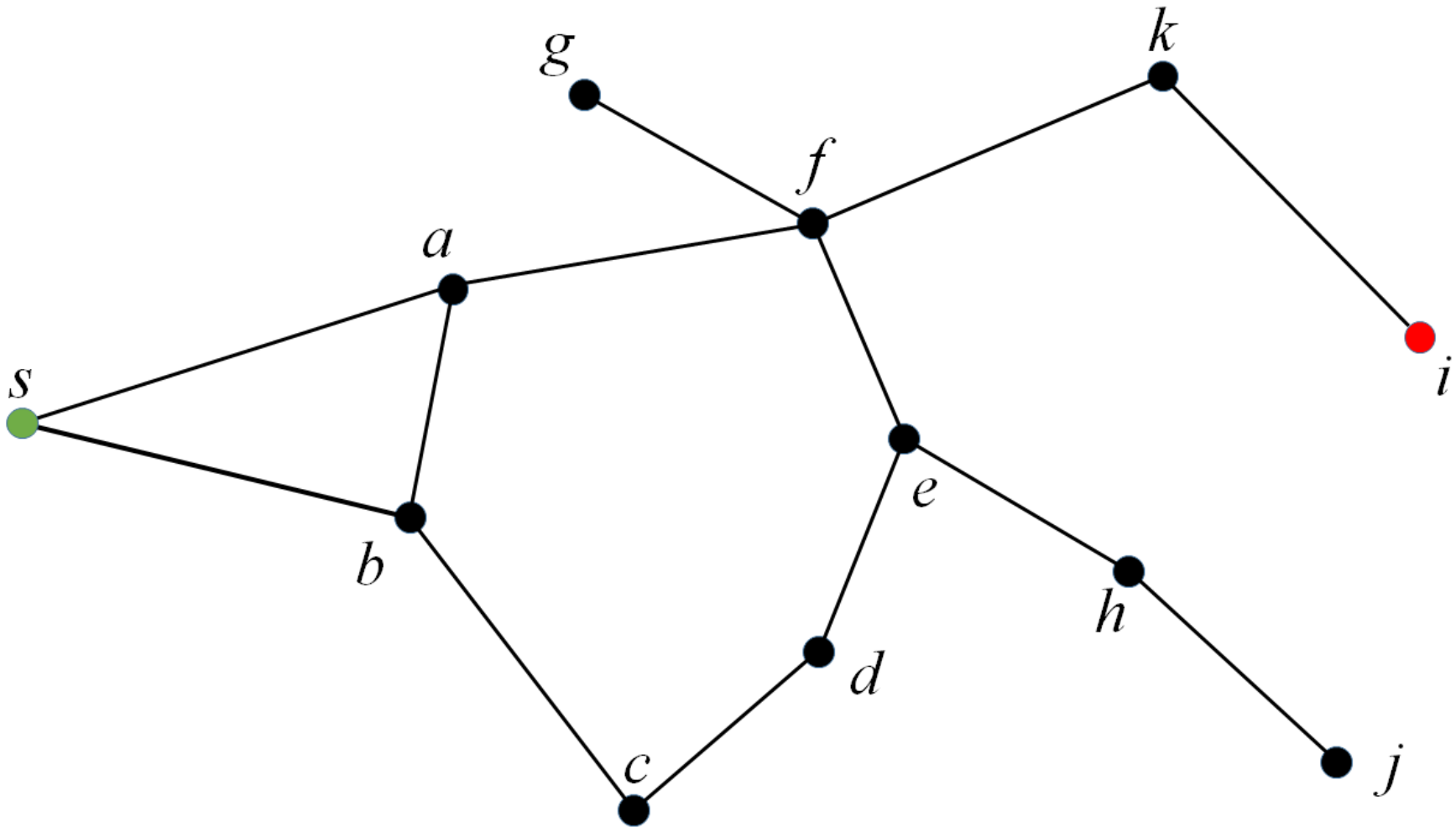


Geometric Routing

- 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



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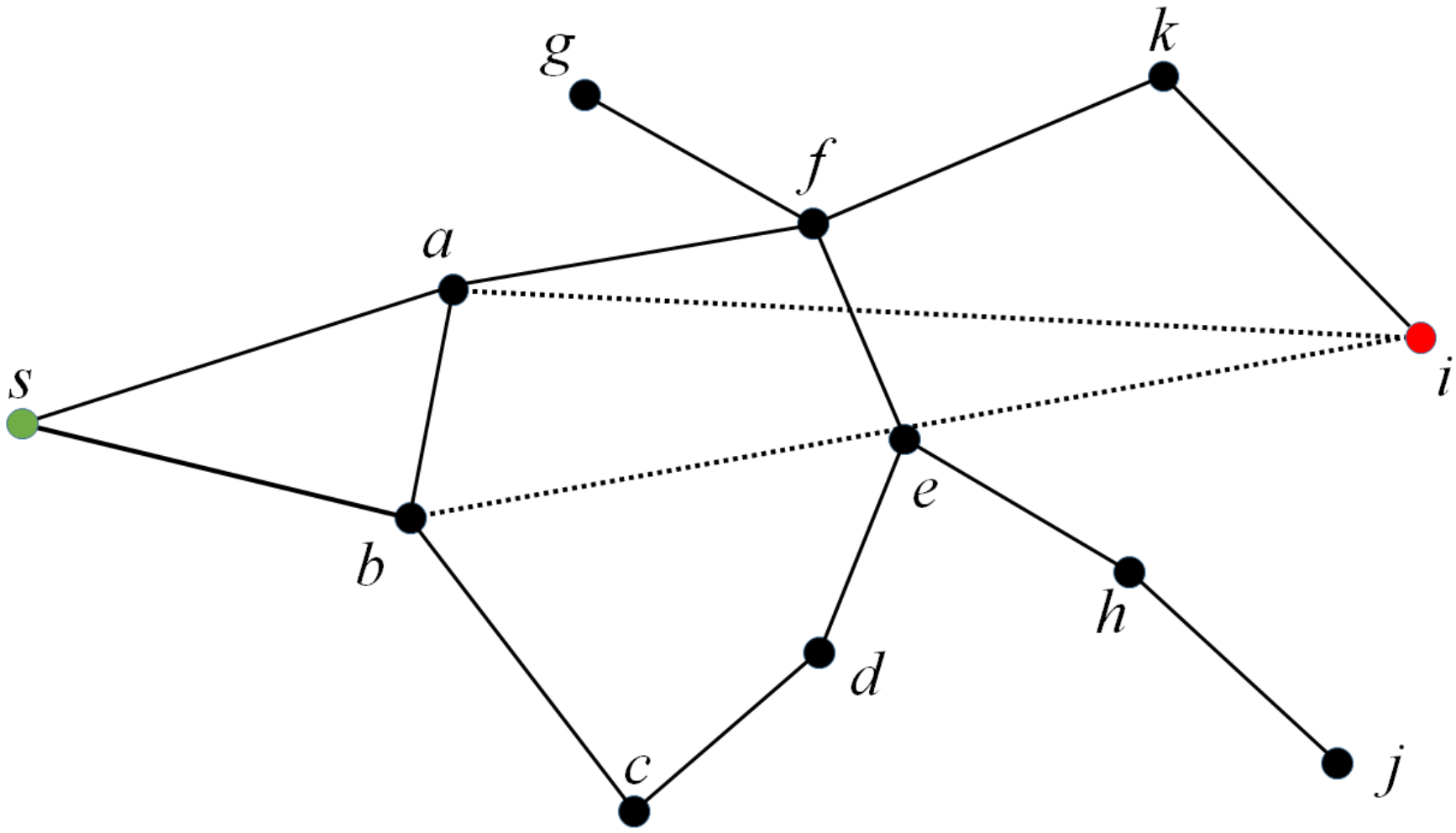

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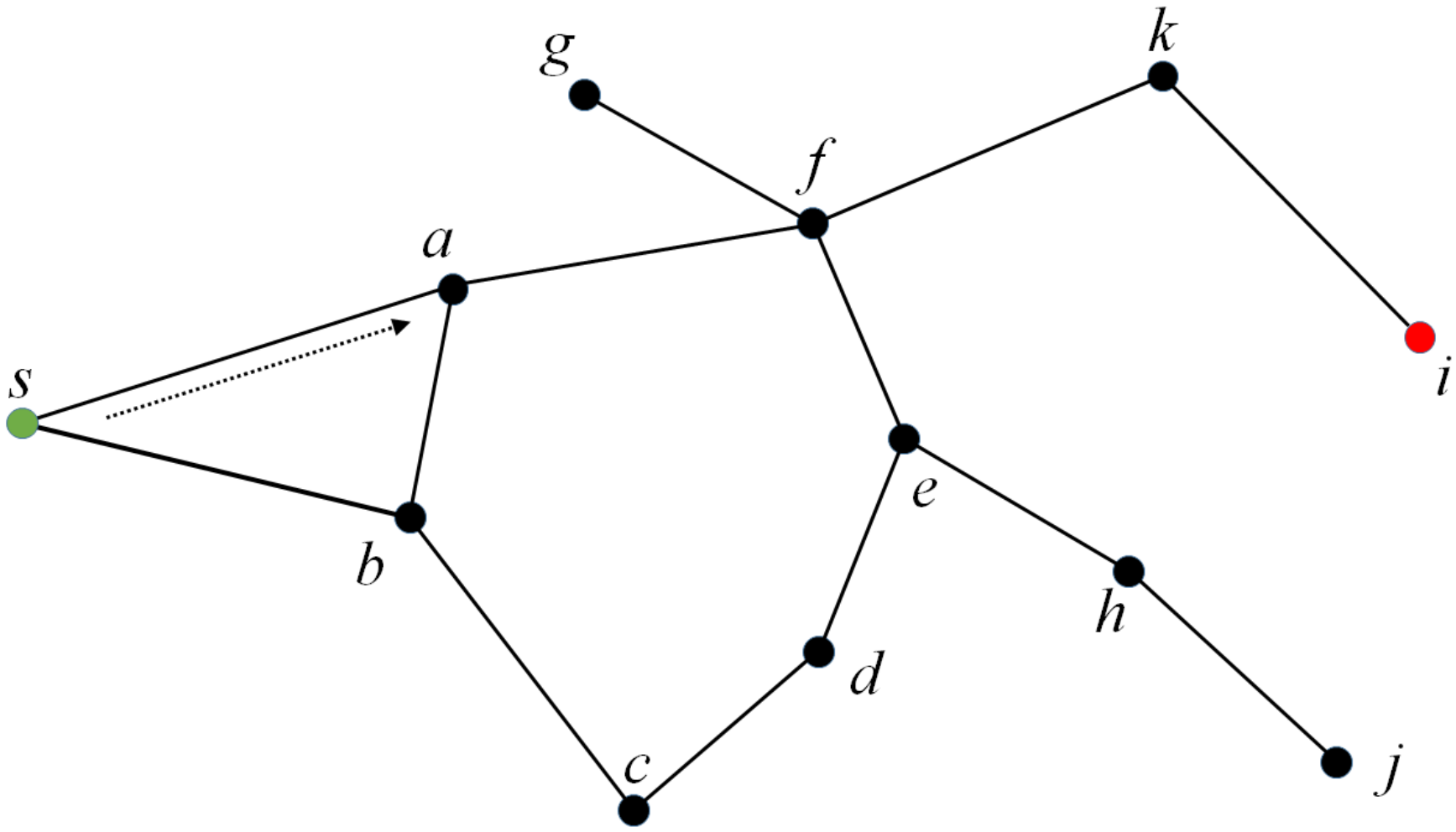

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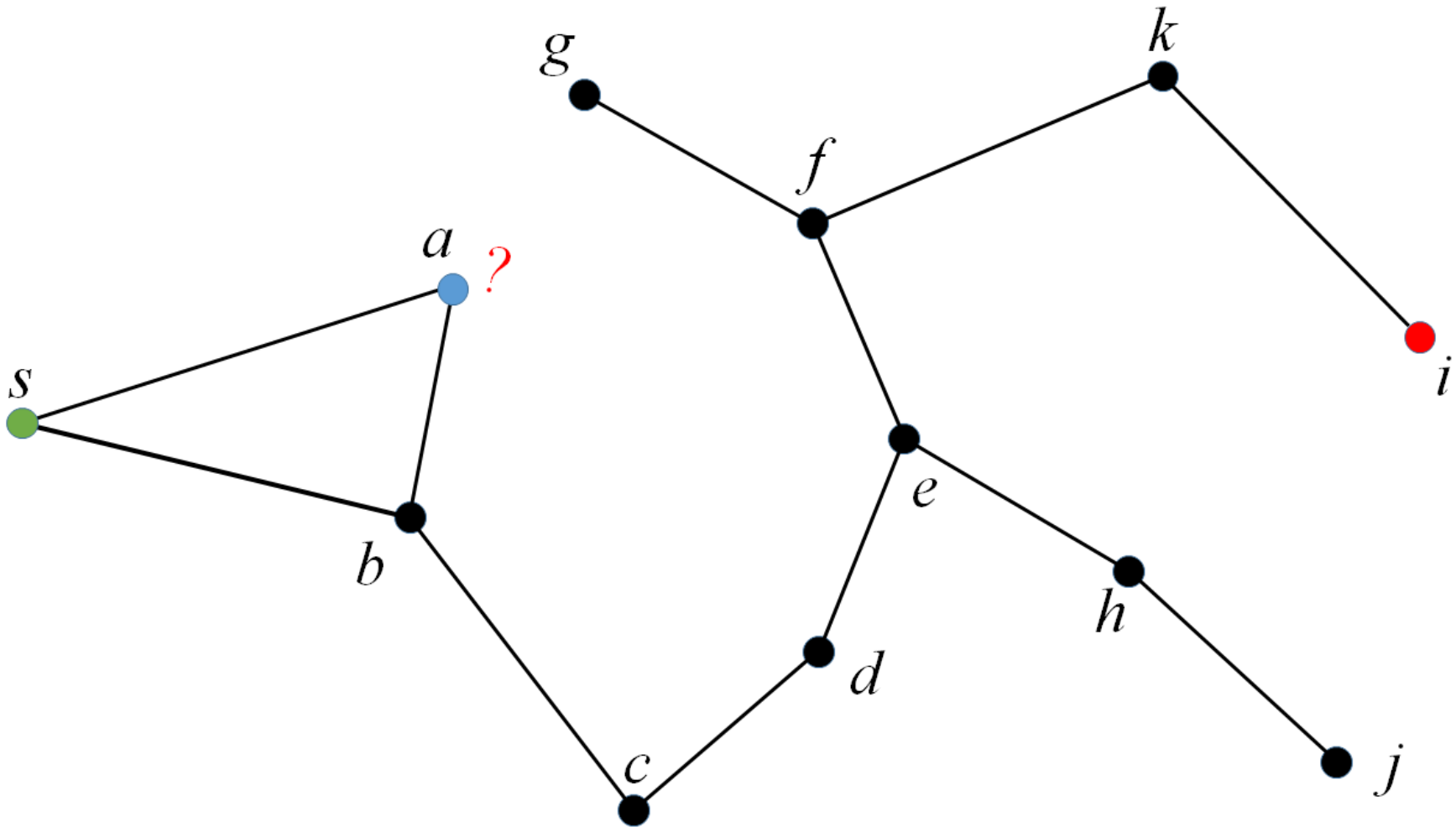
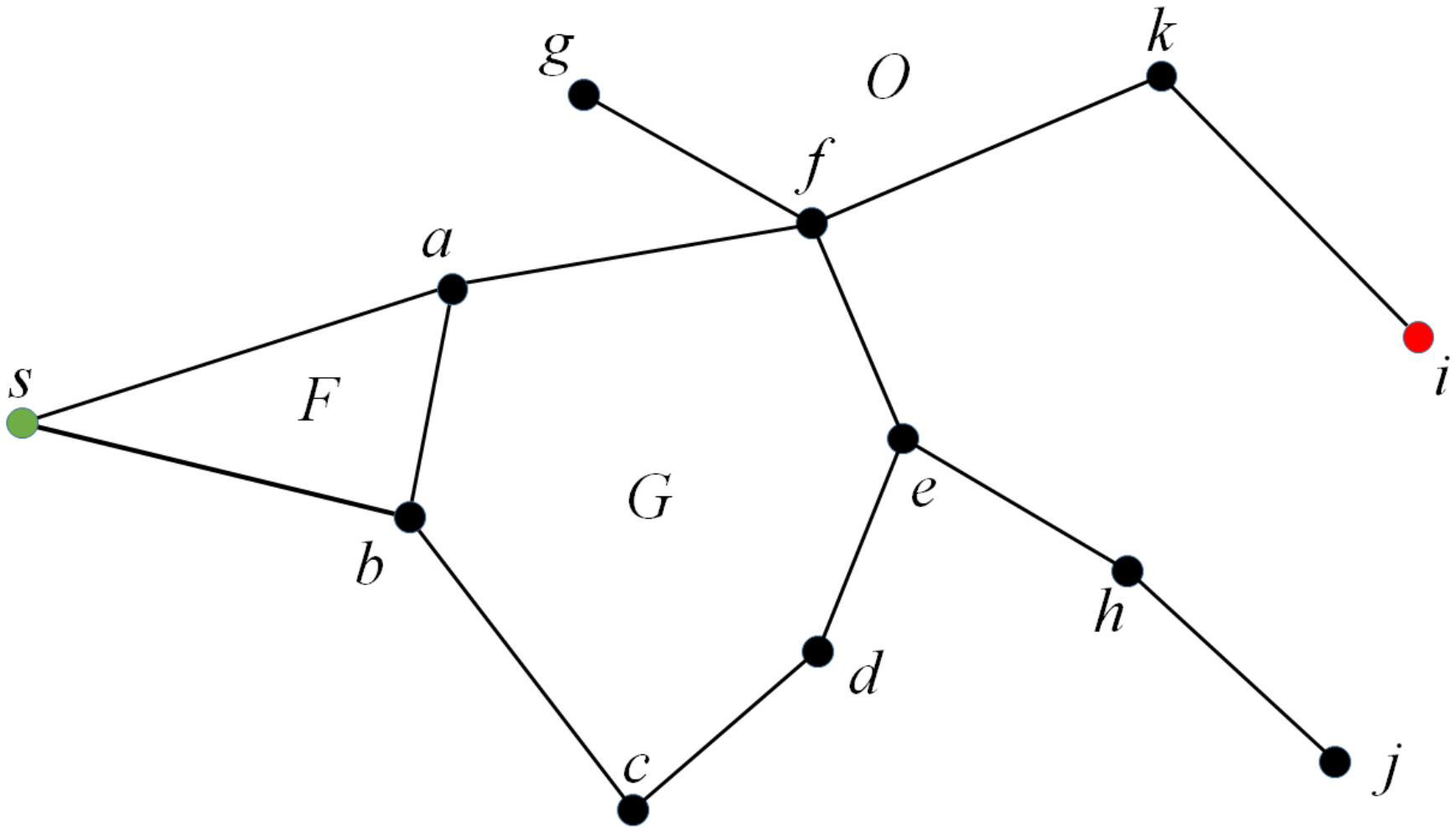
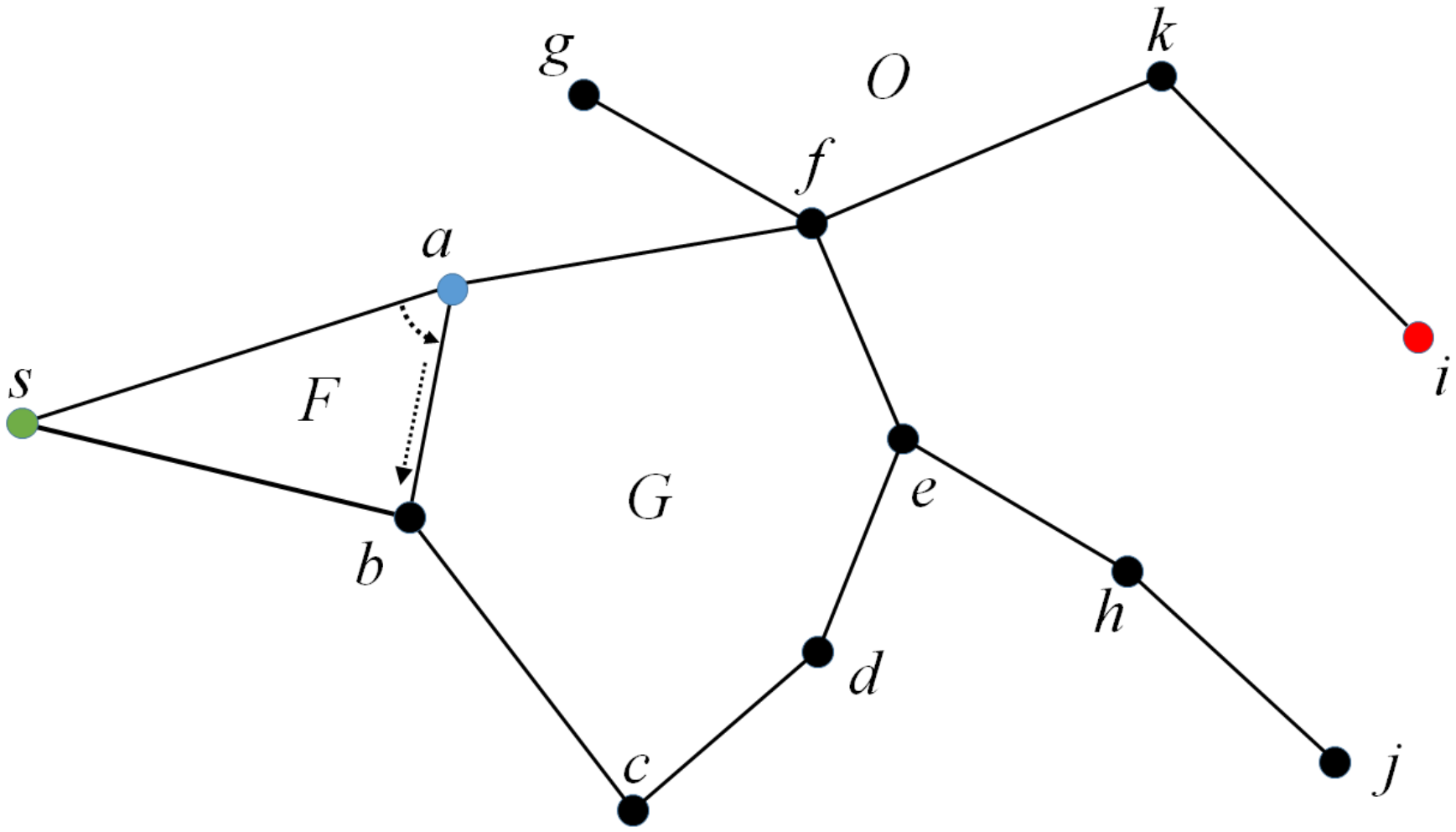


Face Routing



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



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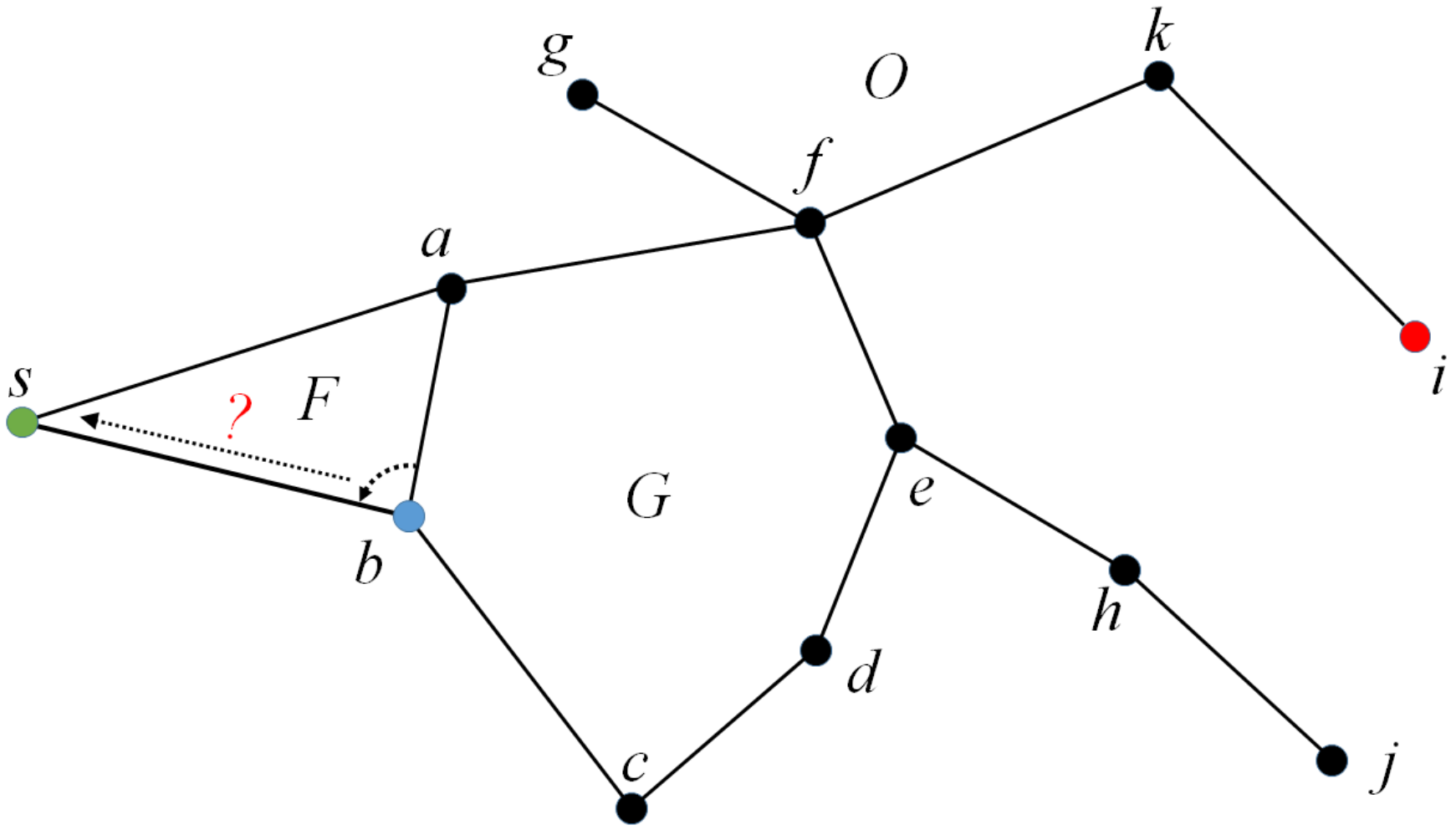

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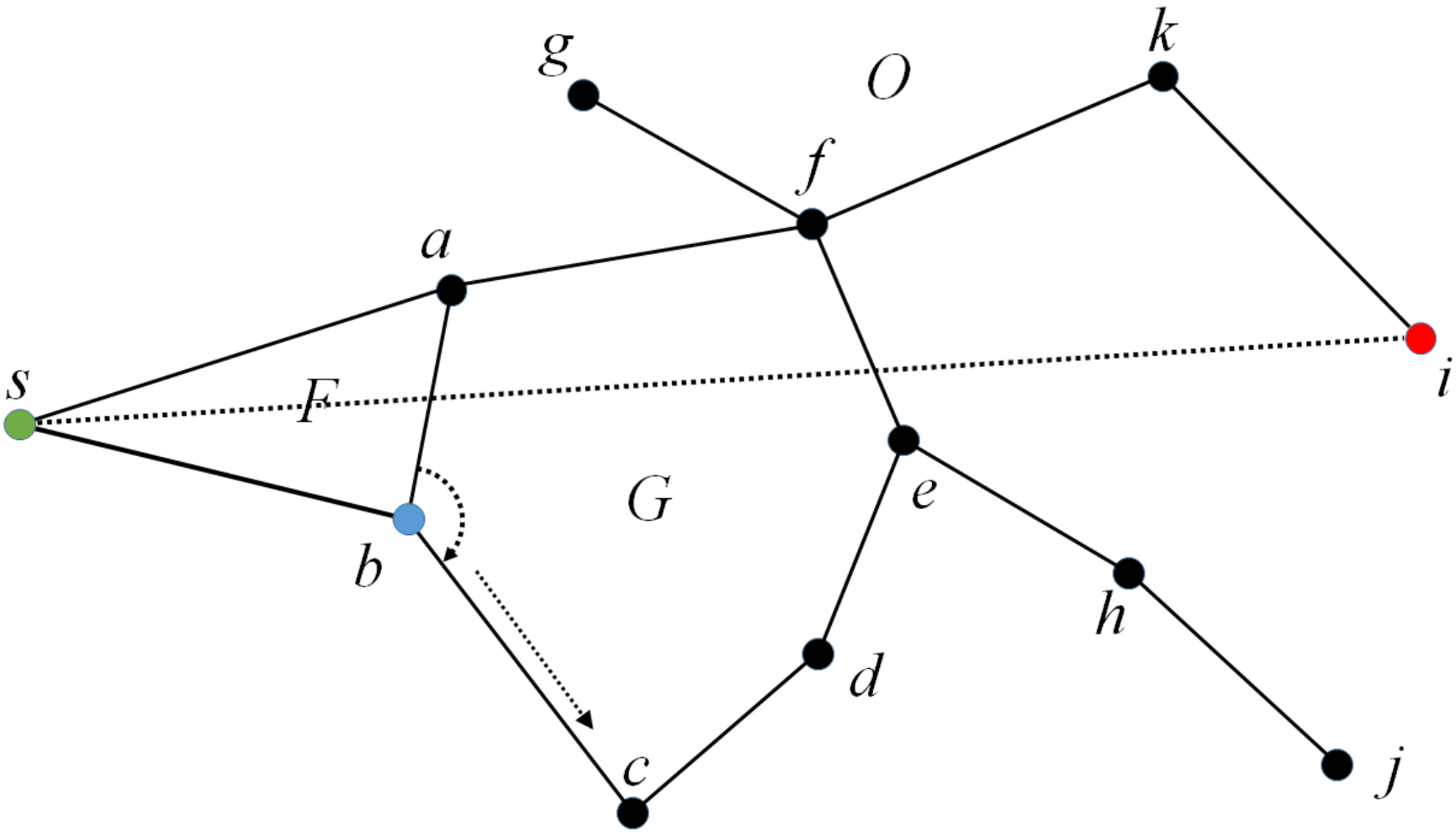

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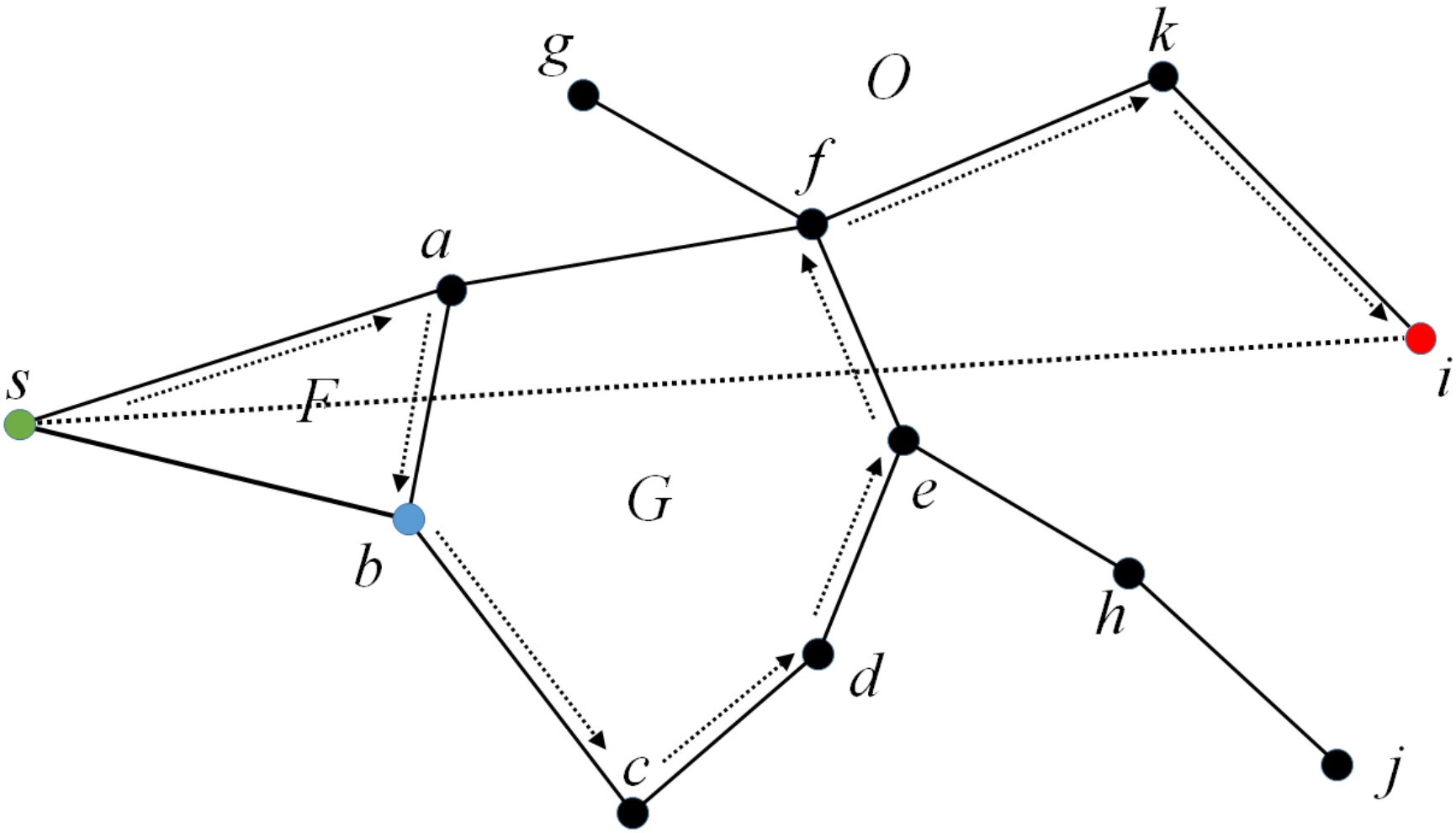
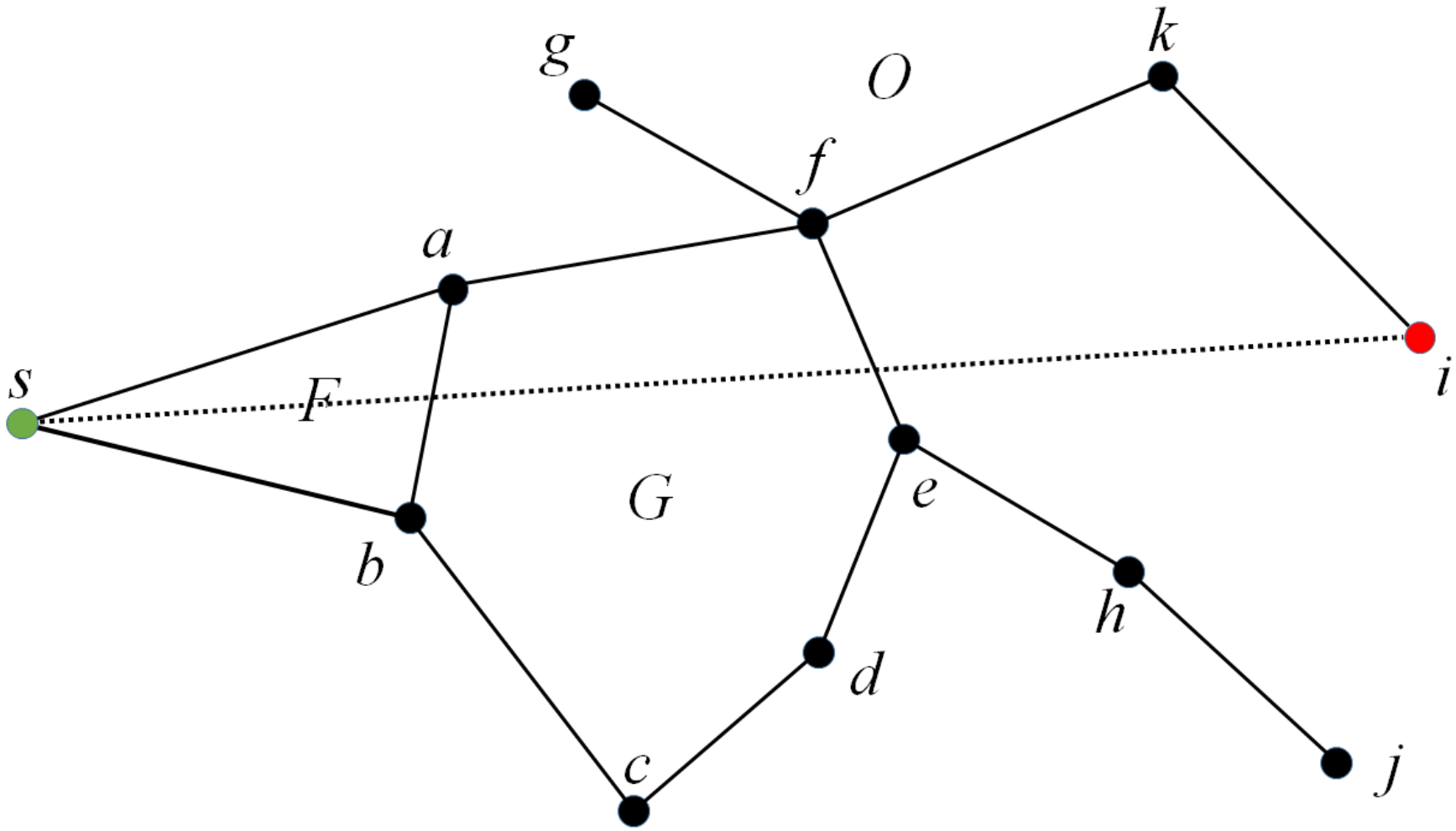
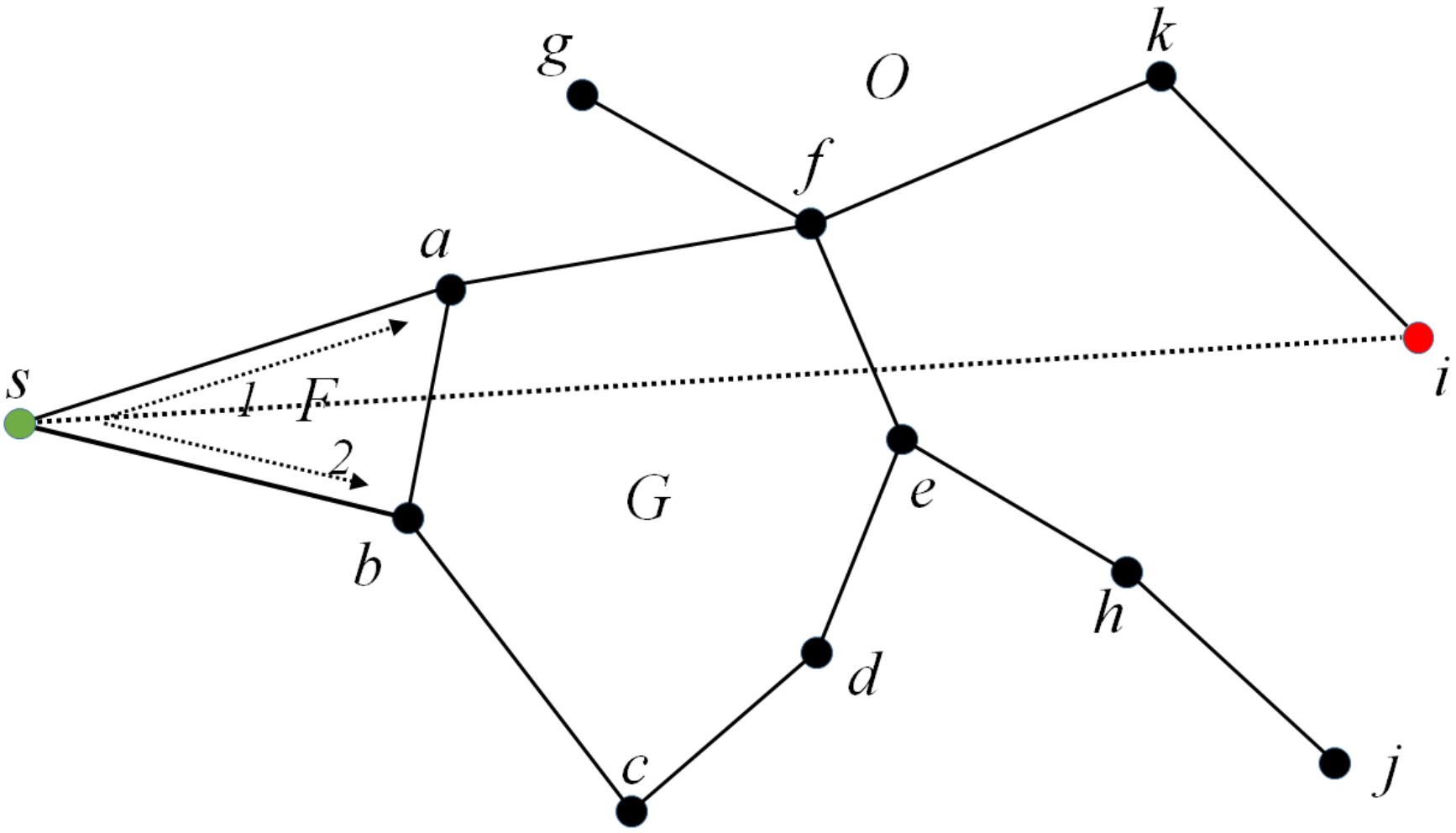


Concurrent Face Routing



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



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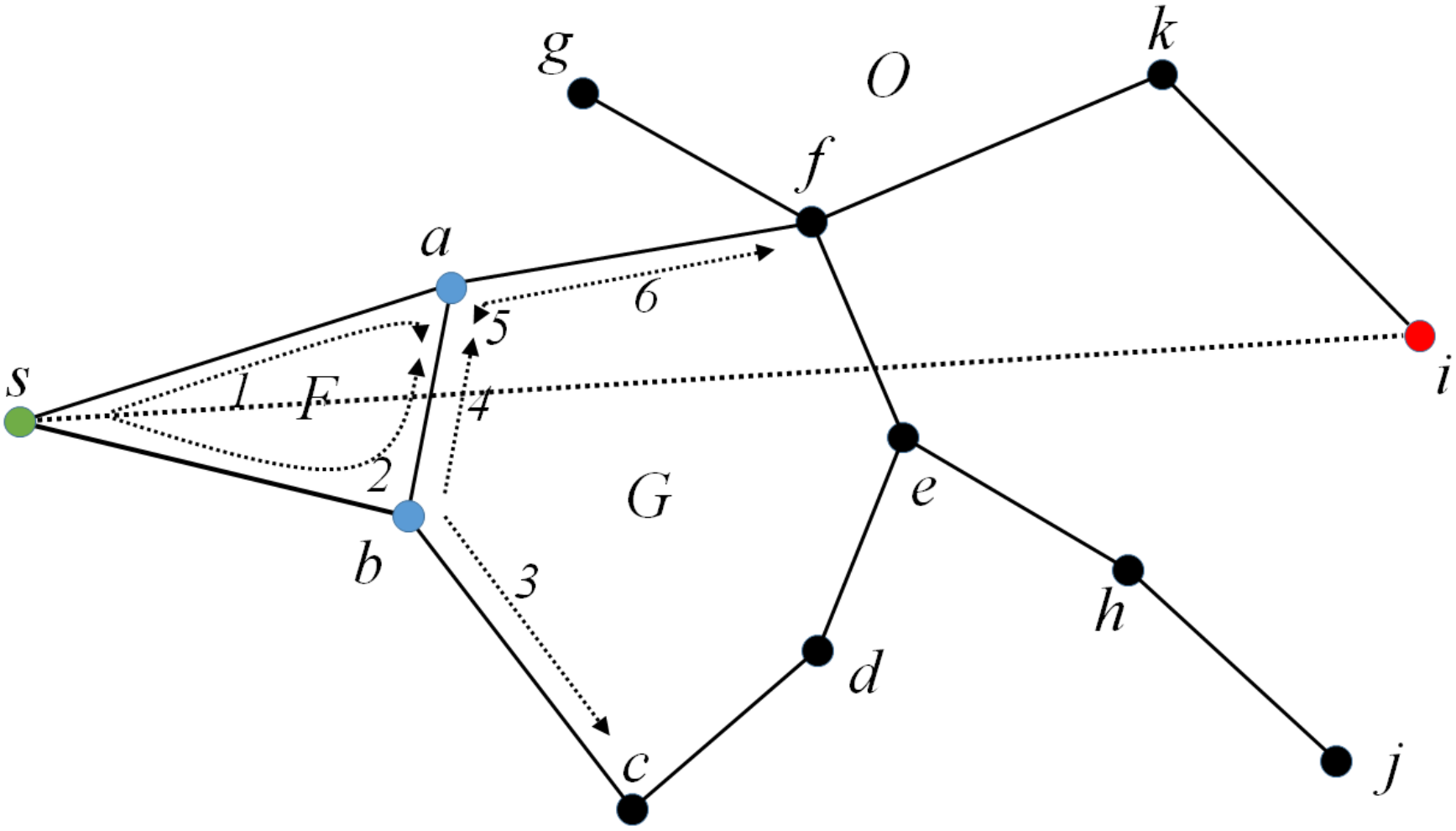
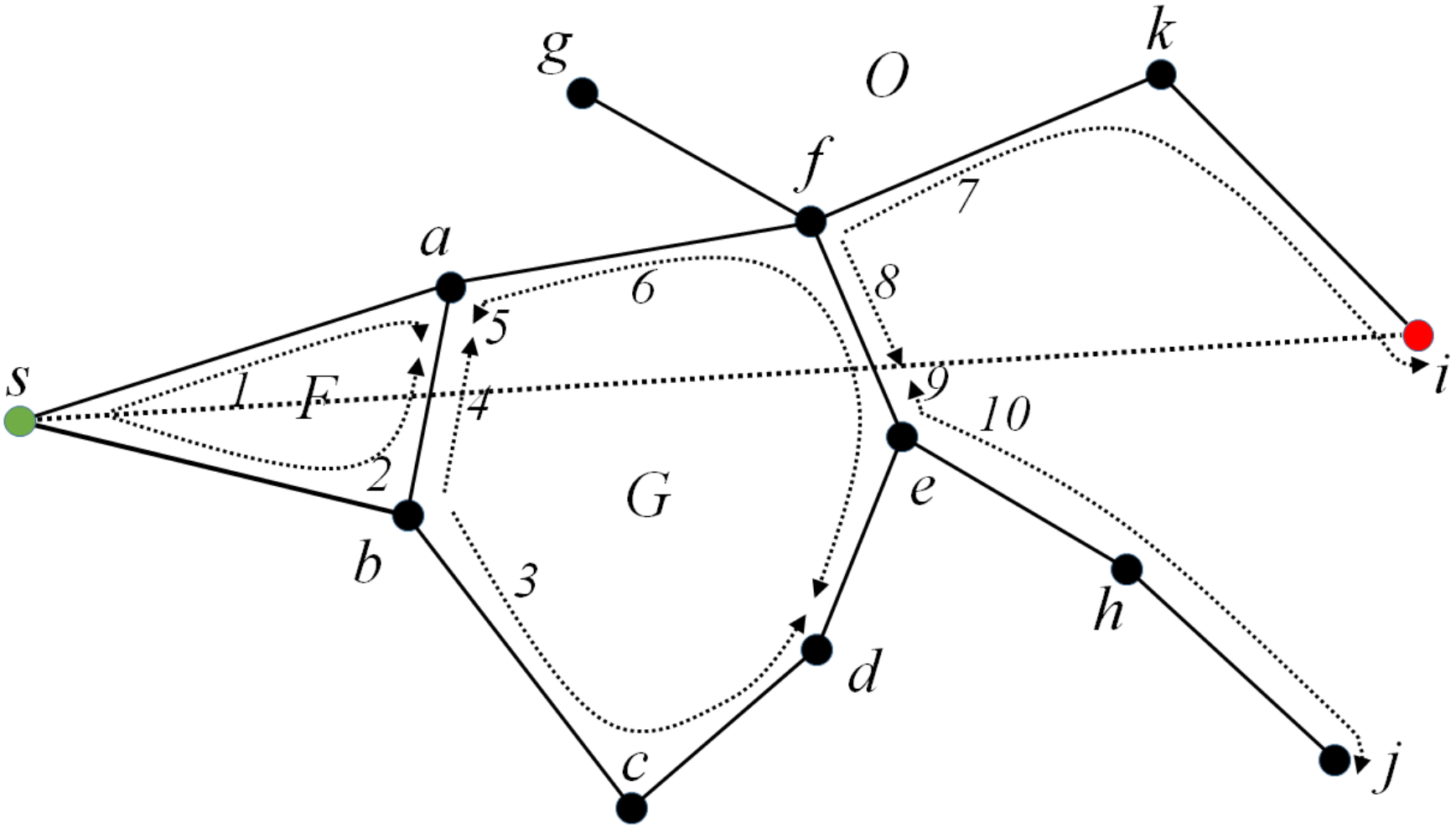


Concurrent Face Routing



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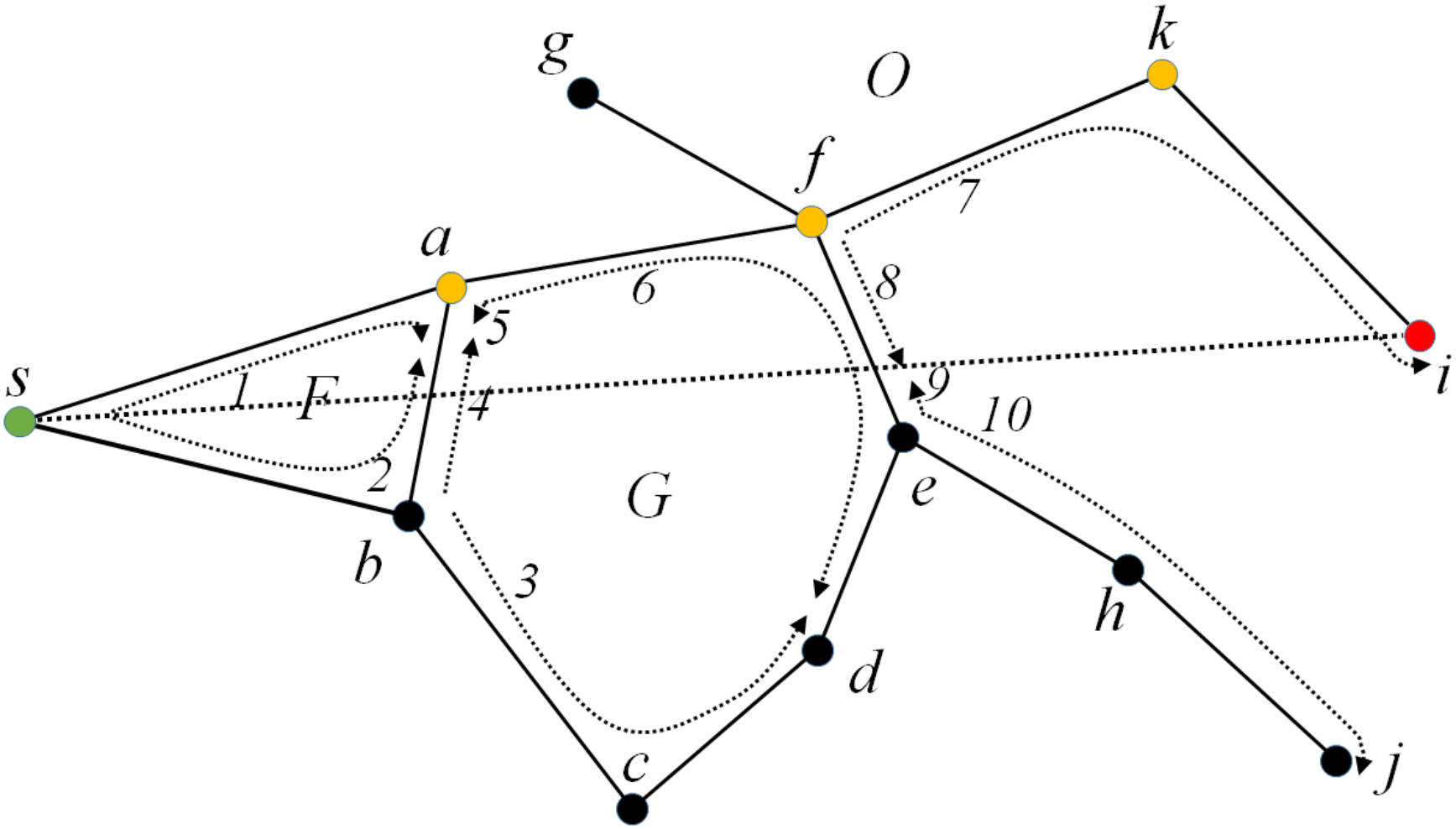
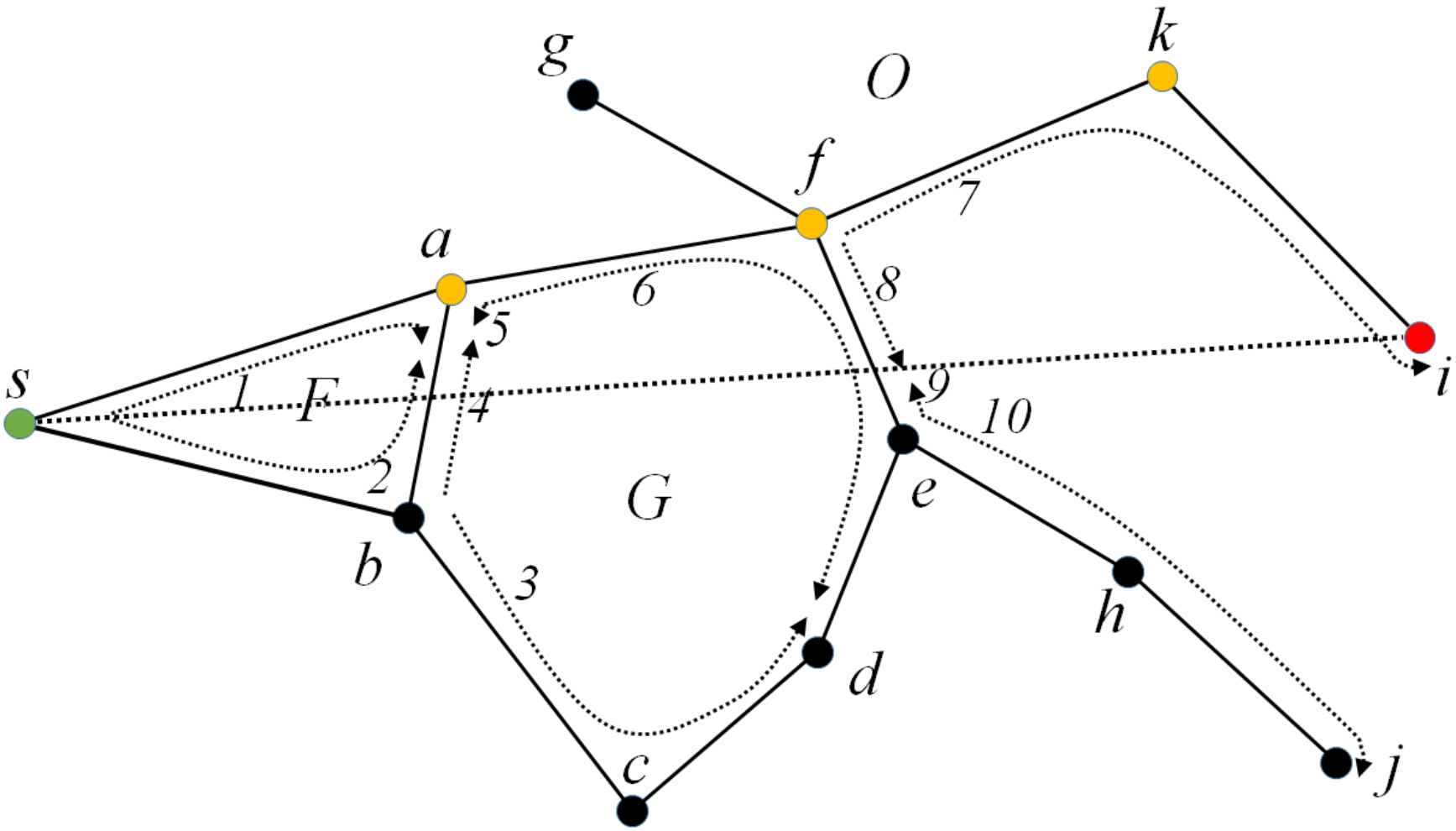


Concurrent Face Routing

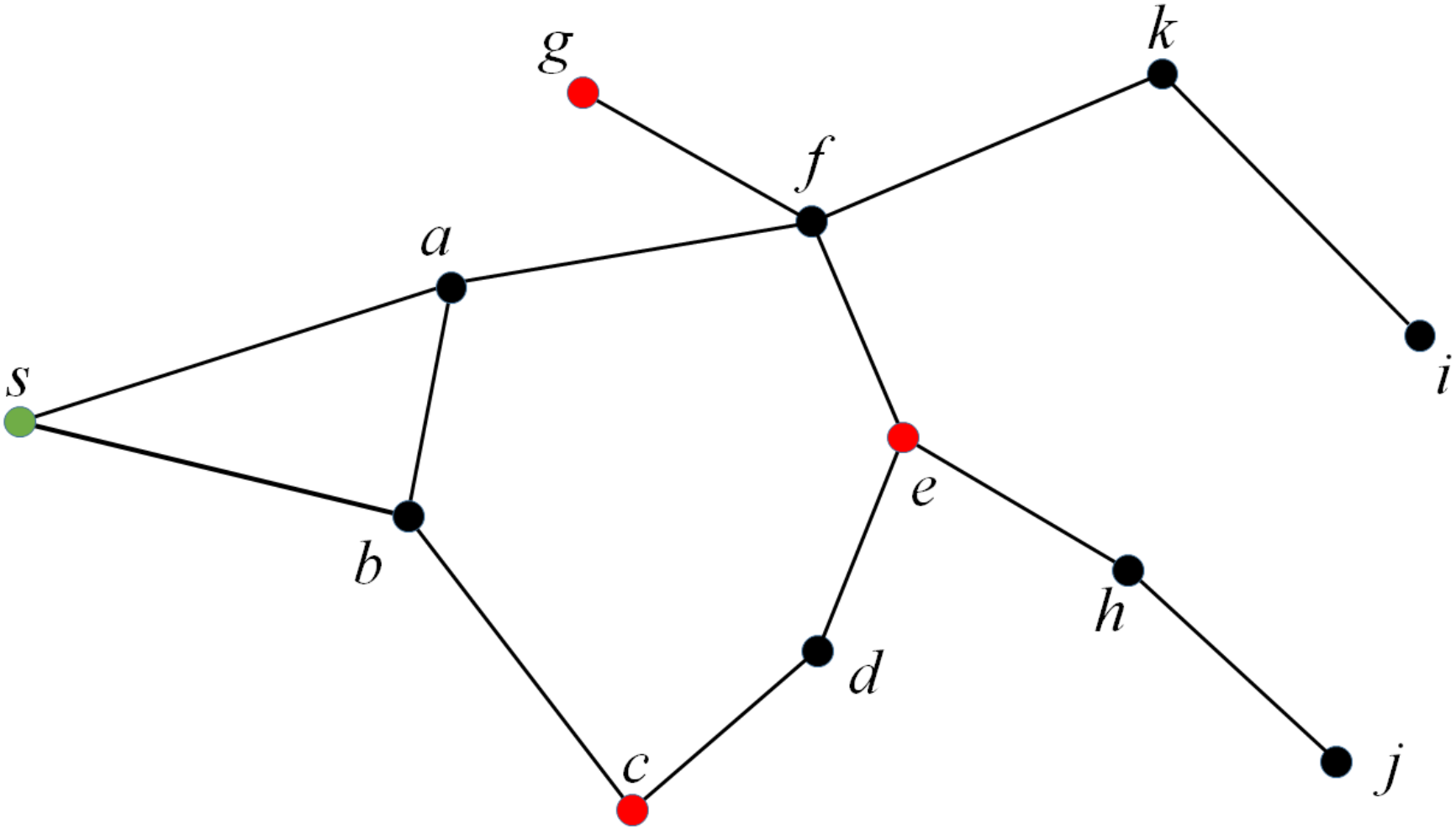


Latency: $O(t^2)$

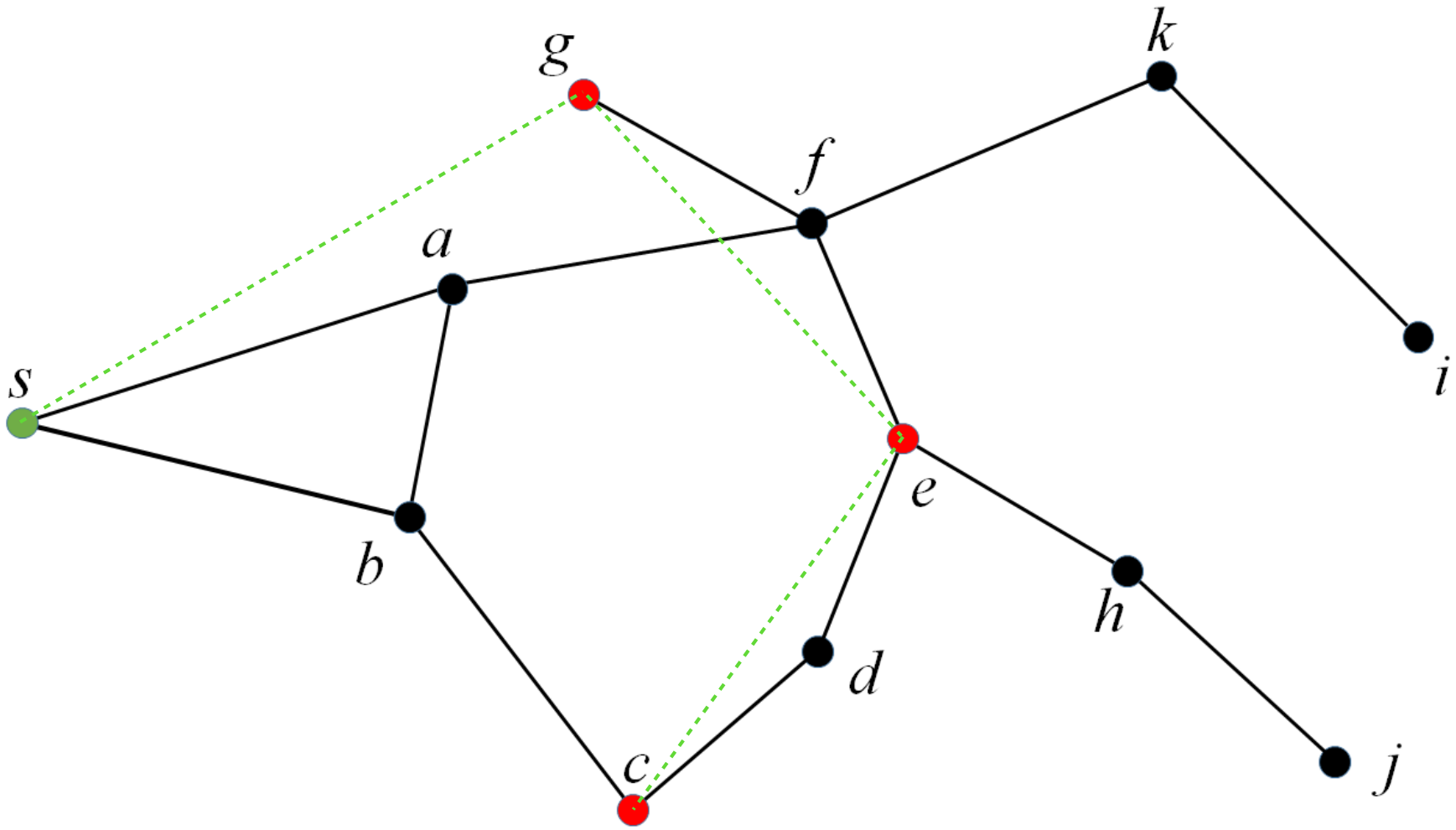
Geometric Multicasting

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

Multicasting

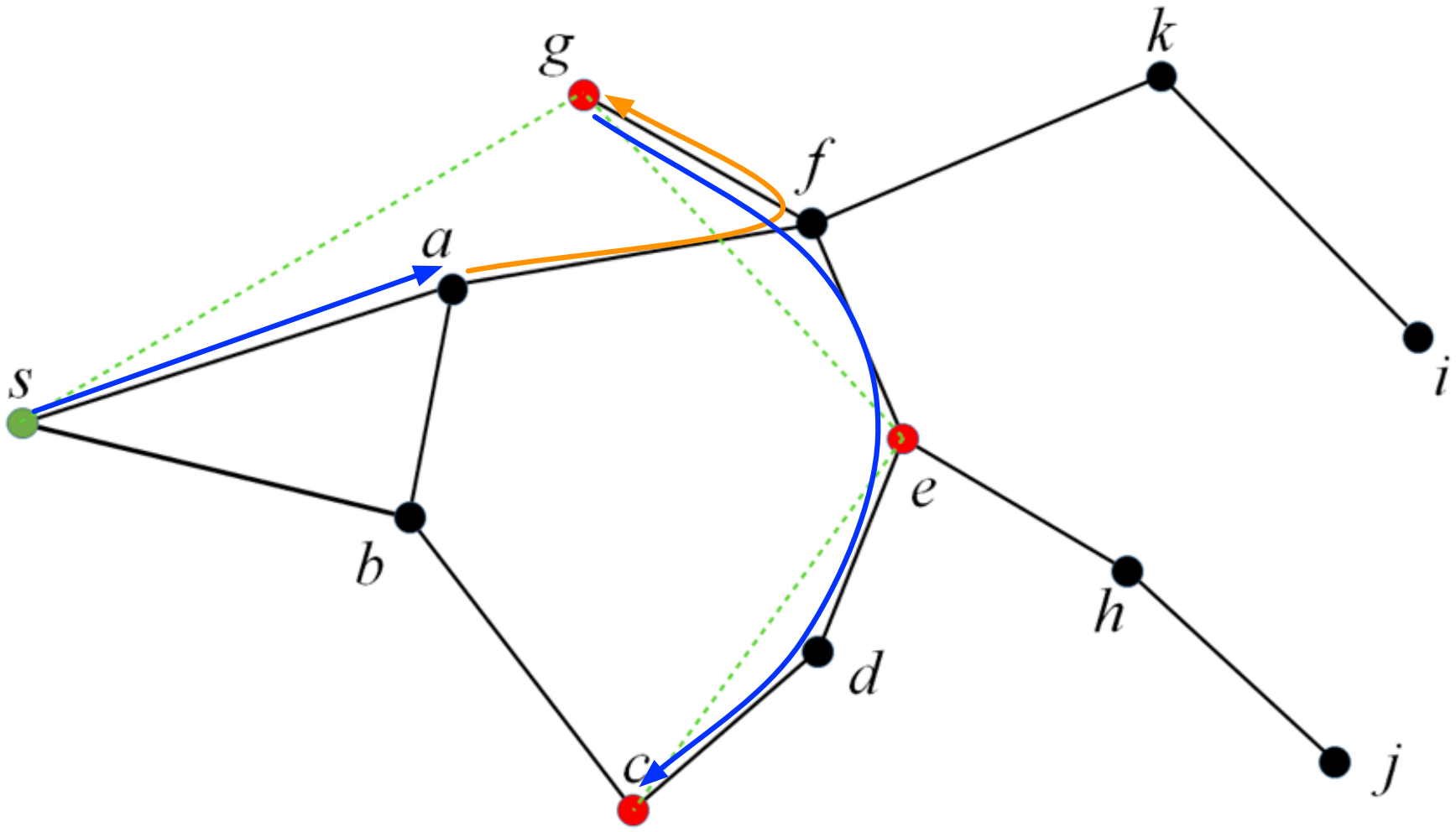


LGS: Euclidean Tree

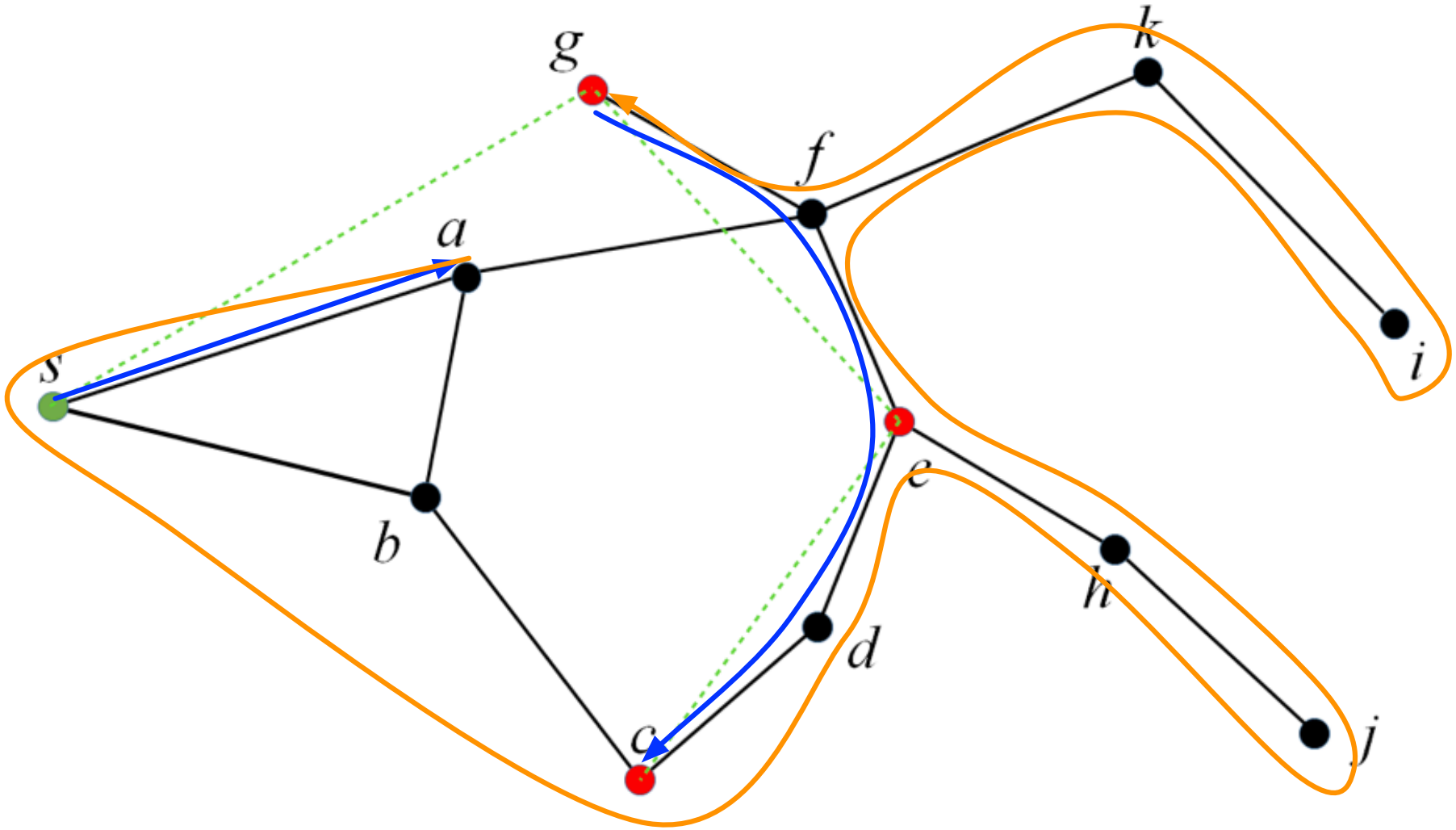


Kai Chen, Klara Nahrstedt: Effective location-guided overlay multicast in mobile ad hoc networks. Int. J. Pervasive Computing and Communications 5(4): 388-410 (2009)

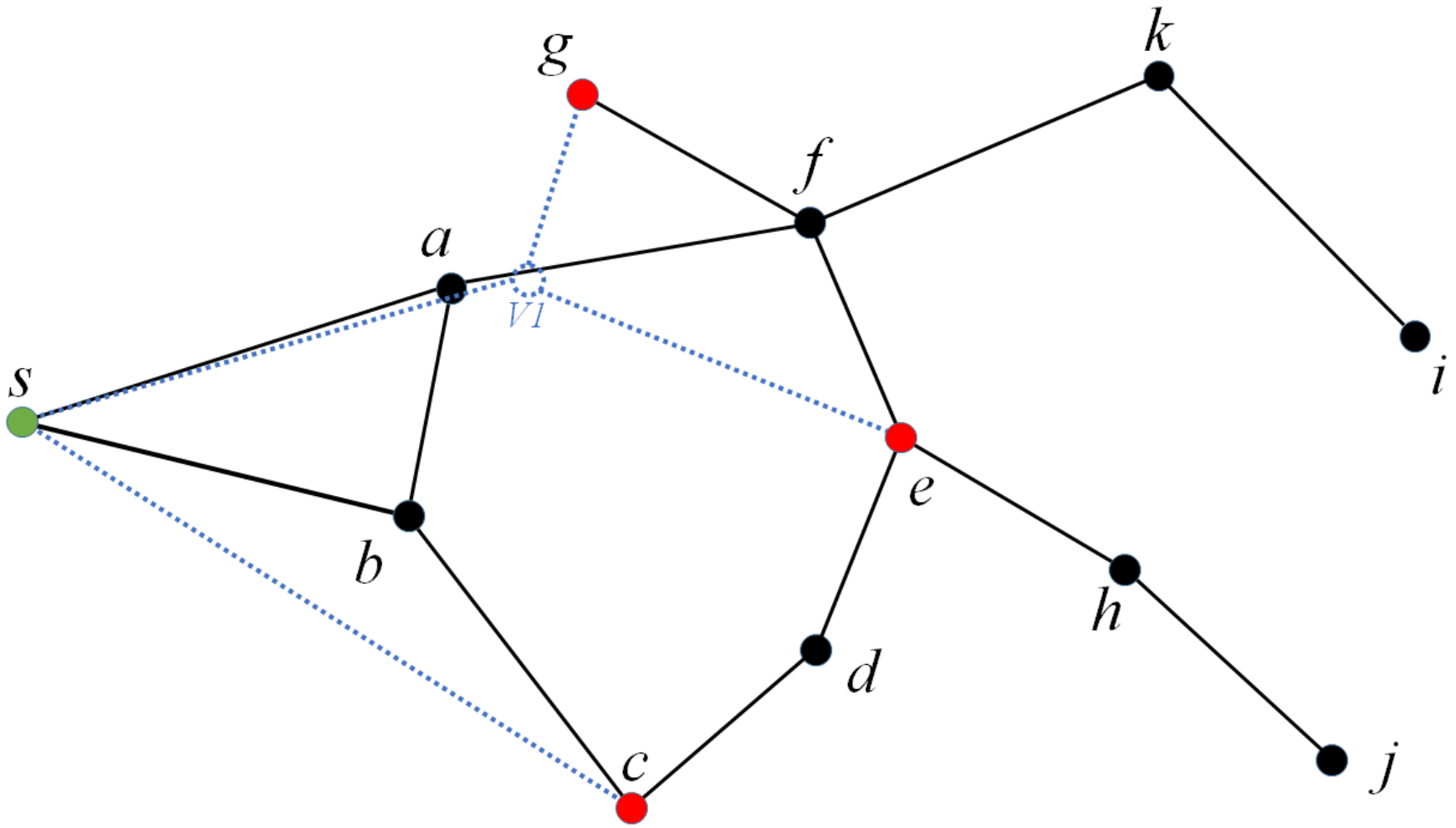
LGS: Euclidean Tree



LGS: Euclidean Tree

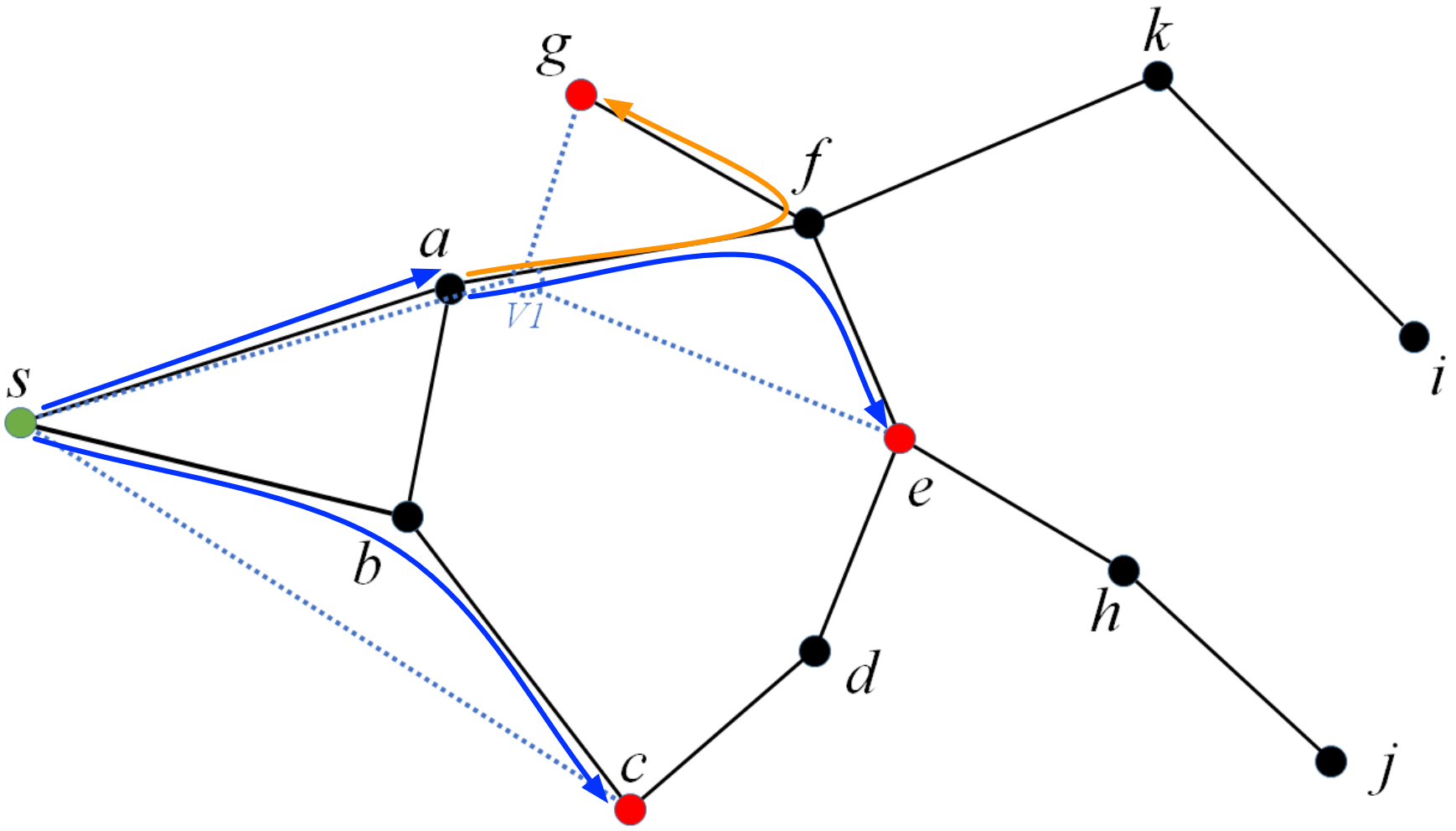


GMP: Virtual Steiner Tree

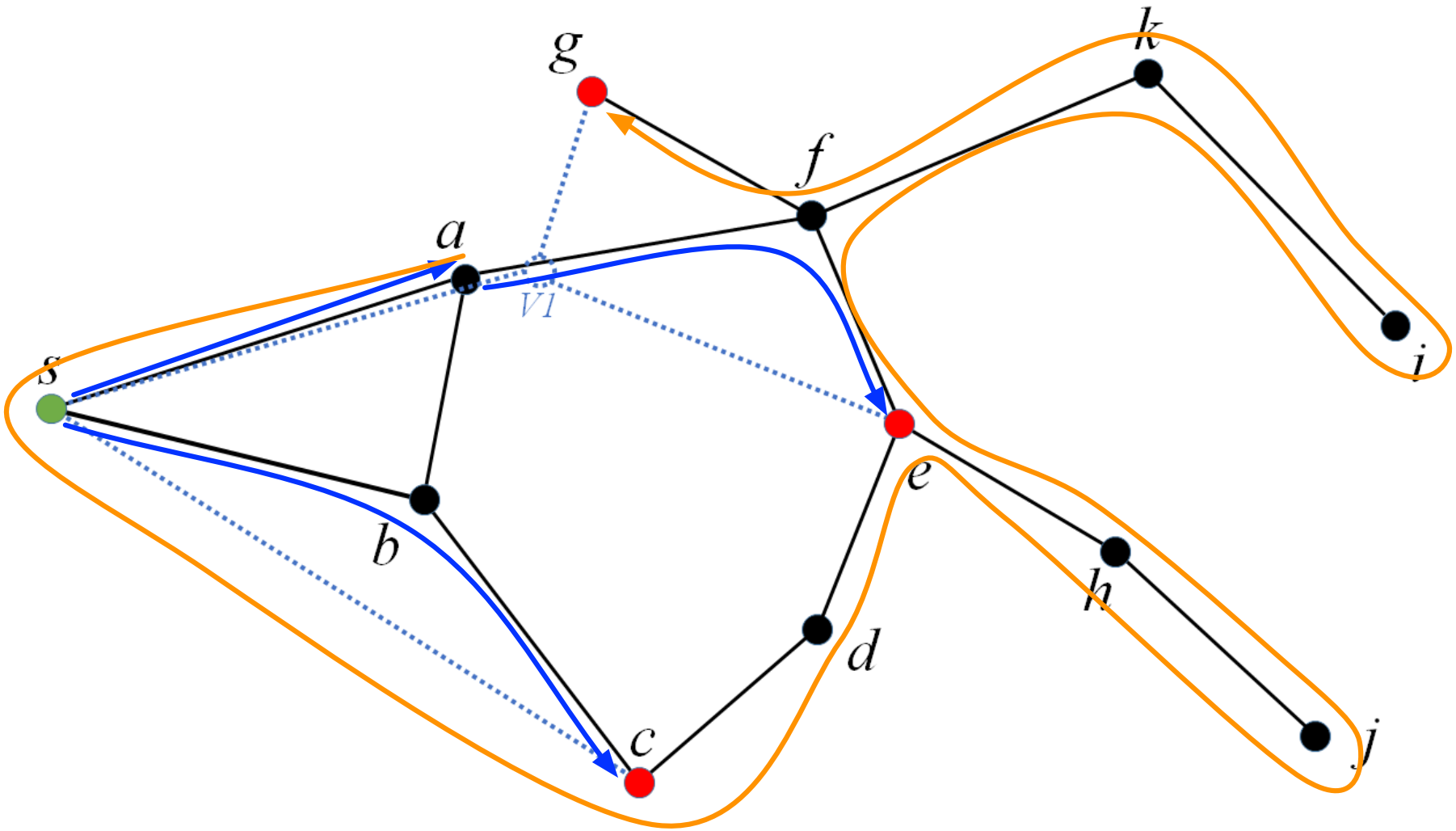


Shibo Wu, K. Selçuk Candan: GMP: Distributed Geographic Multicast Routing in Wireless Sensor Networks. ICDCS 2006: 49

GMP: Virtual Steiner Tree

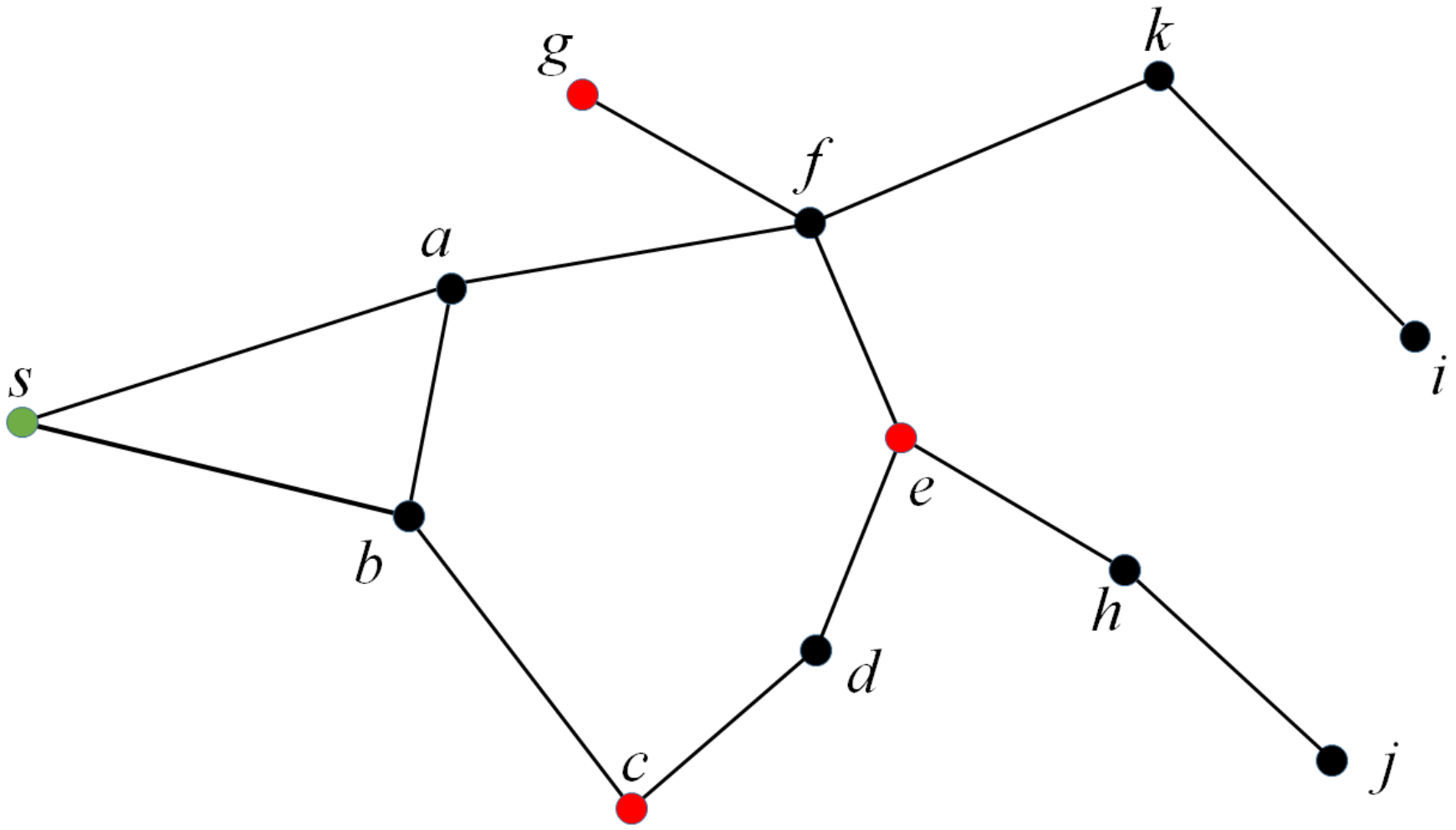


GMP: Virtual Steiner Tree

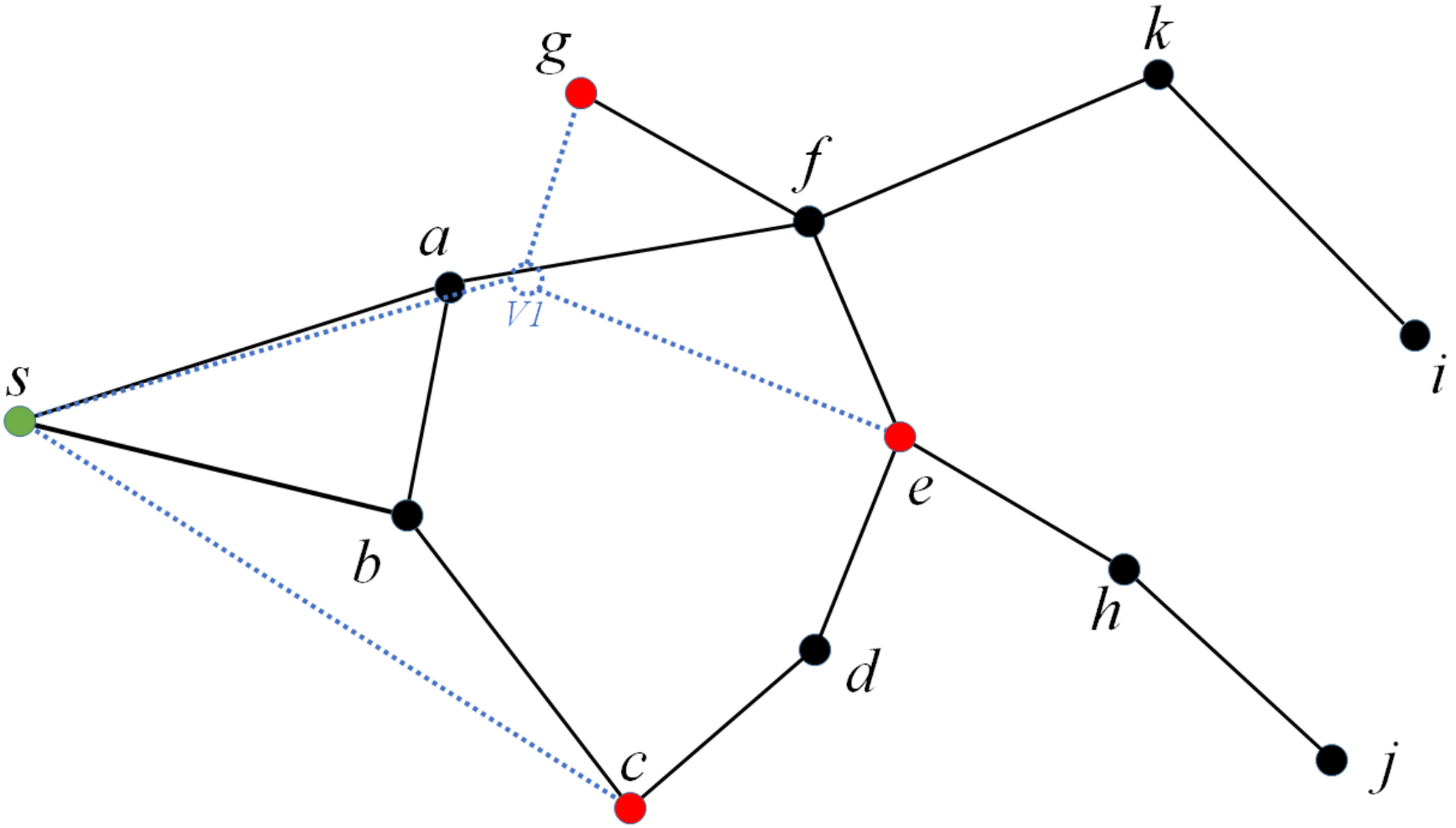


Our Contribution

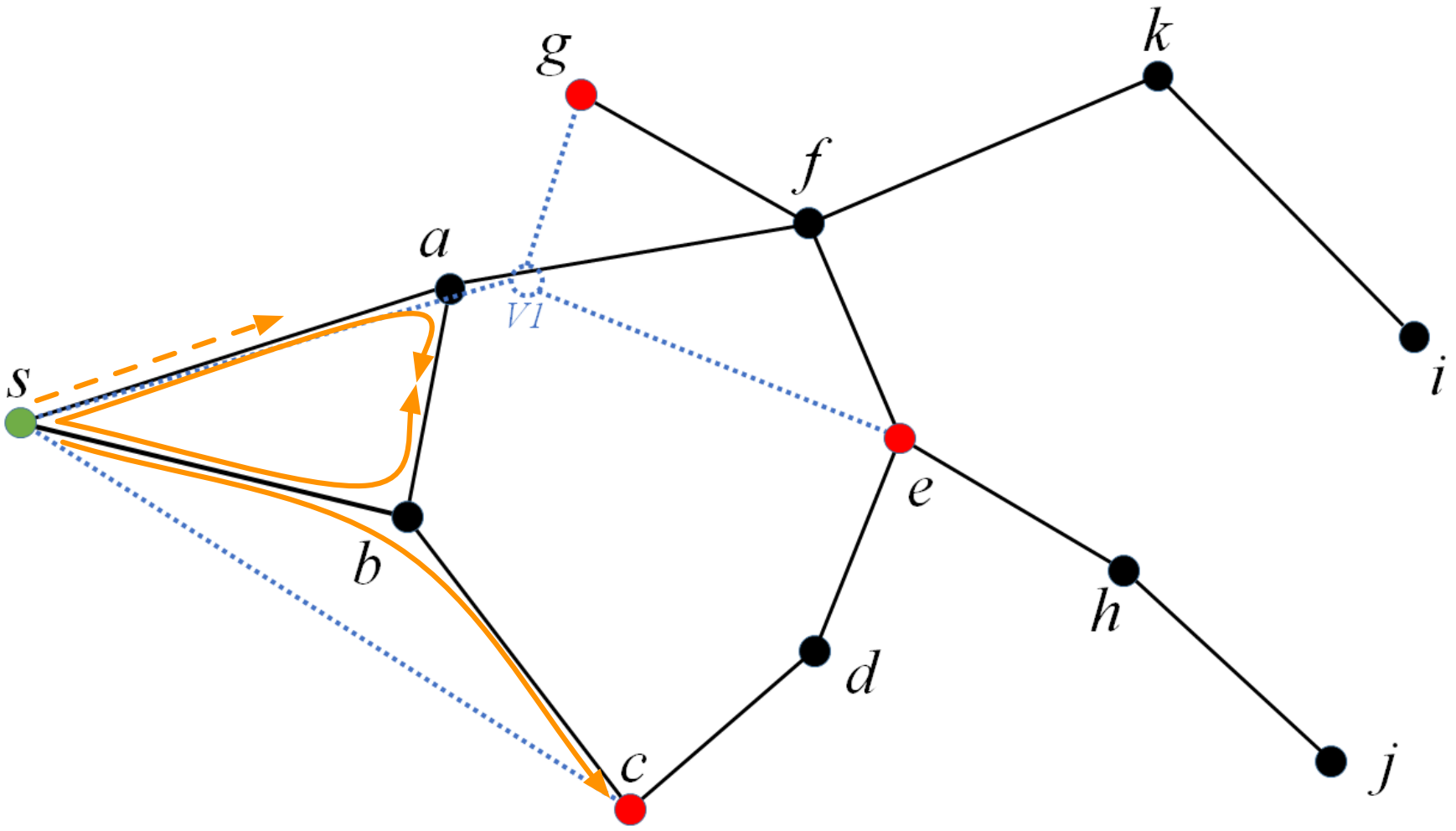
Concurrent Multicasting



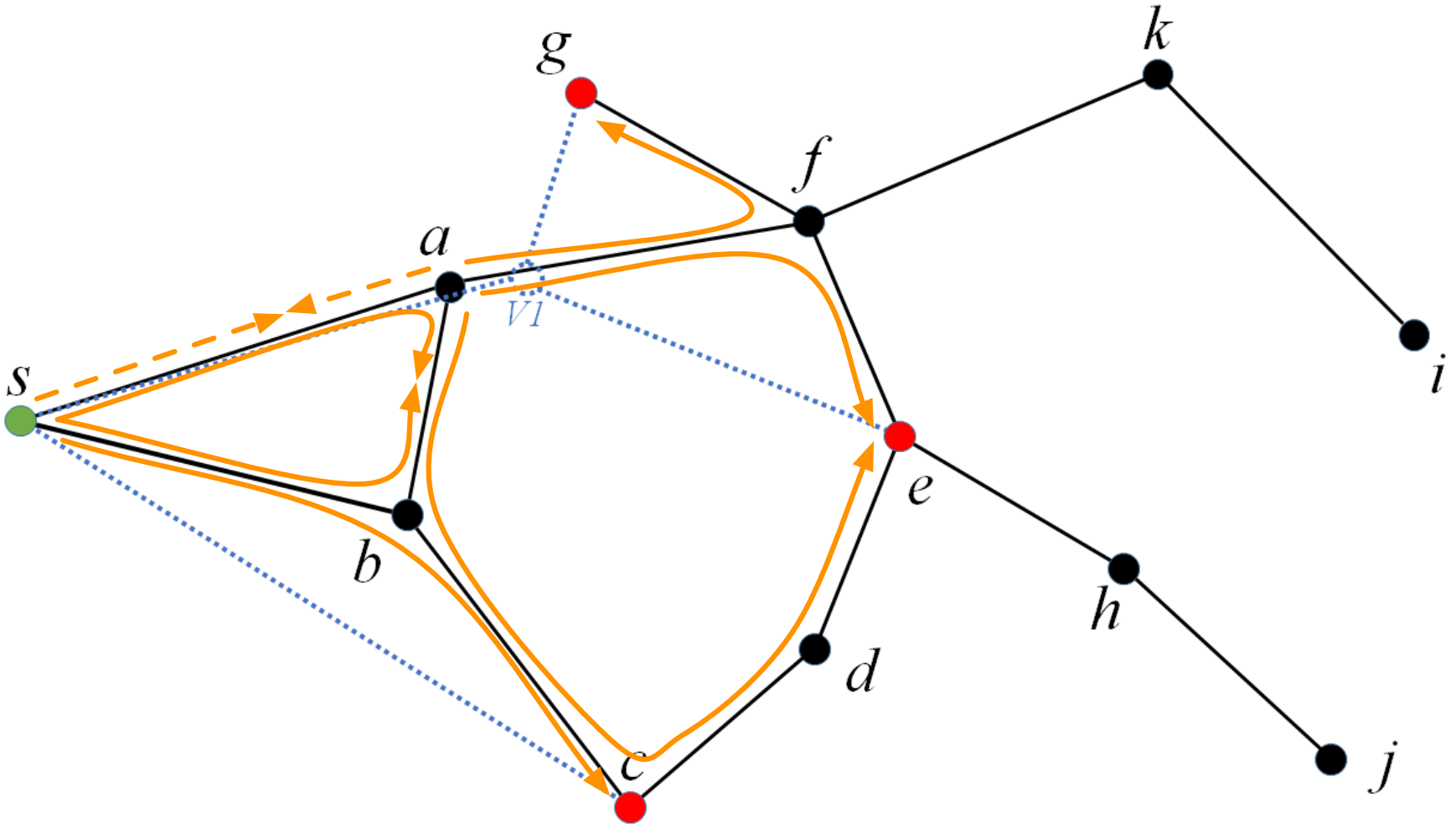
Concurrent Multicasting



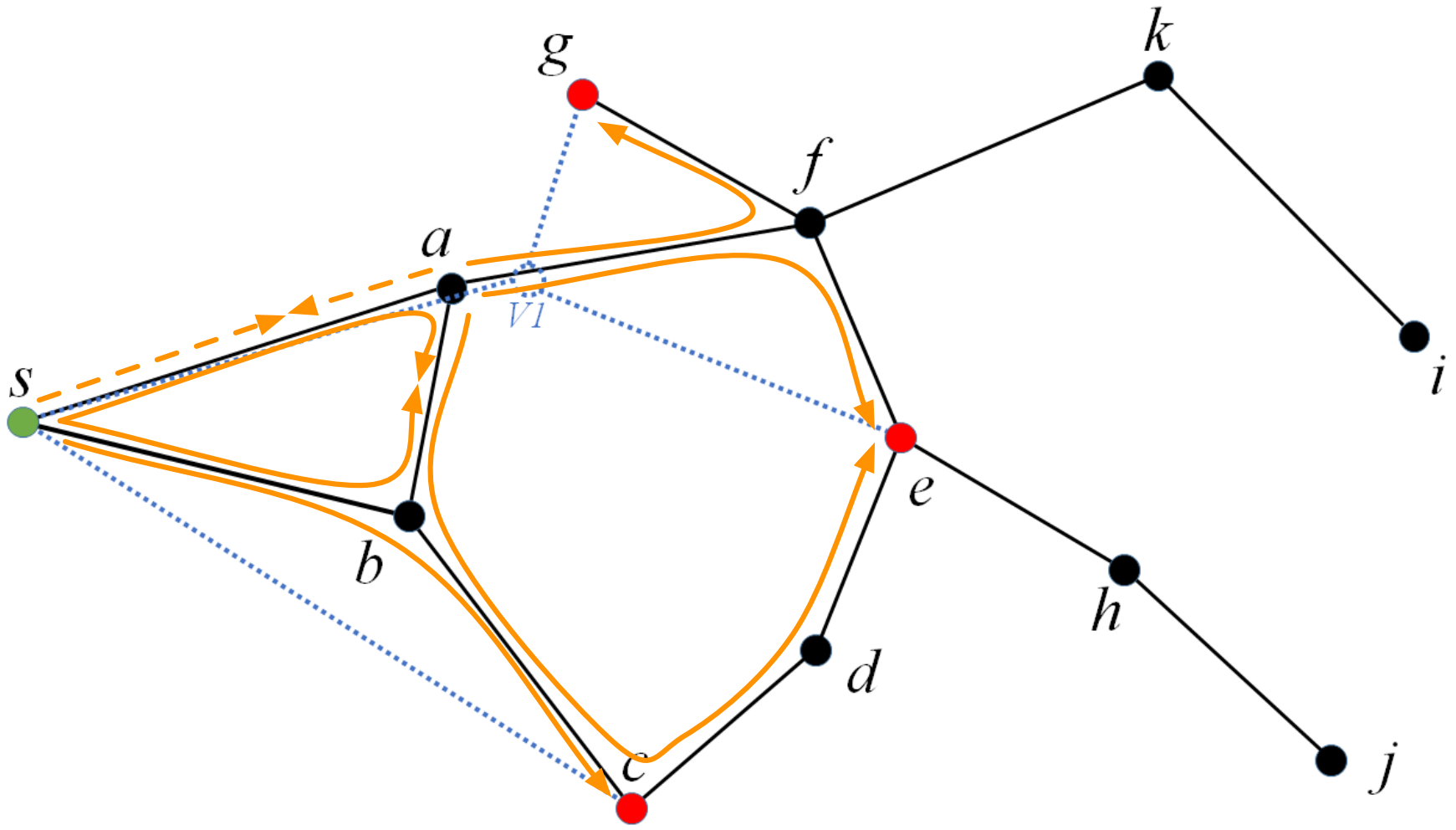
Concurrent Multicasting



Concurrent Multicasting



Concurrent Multicasting



Latency: O(d²)

Experimental Results

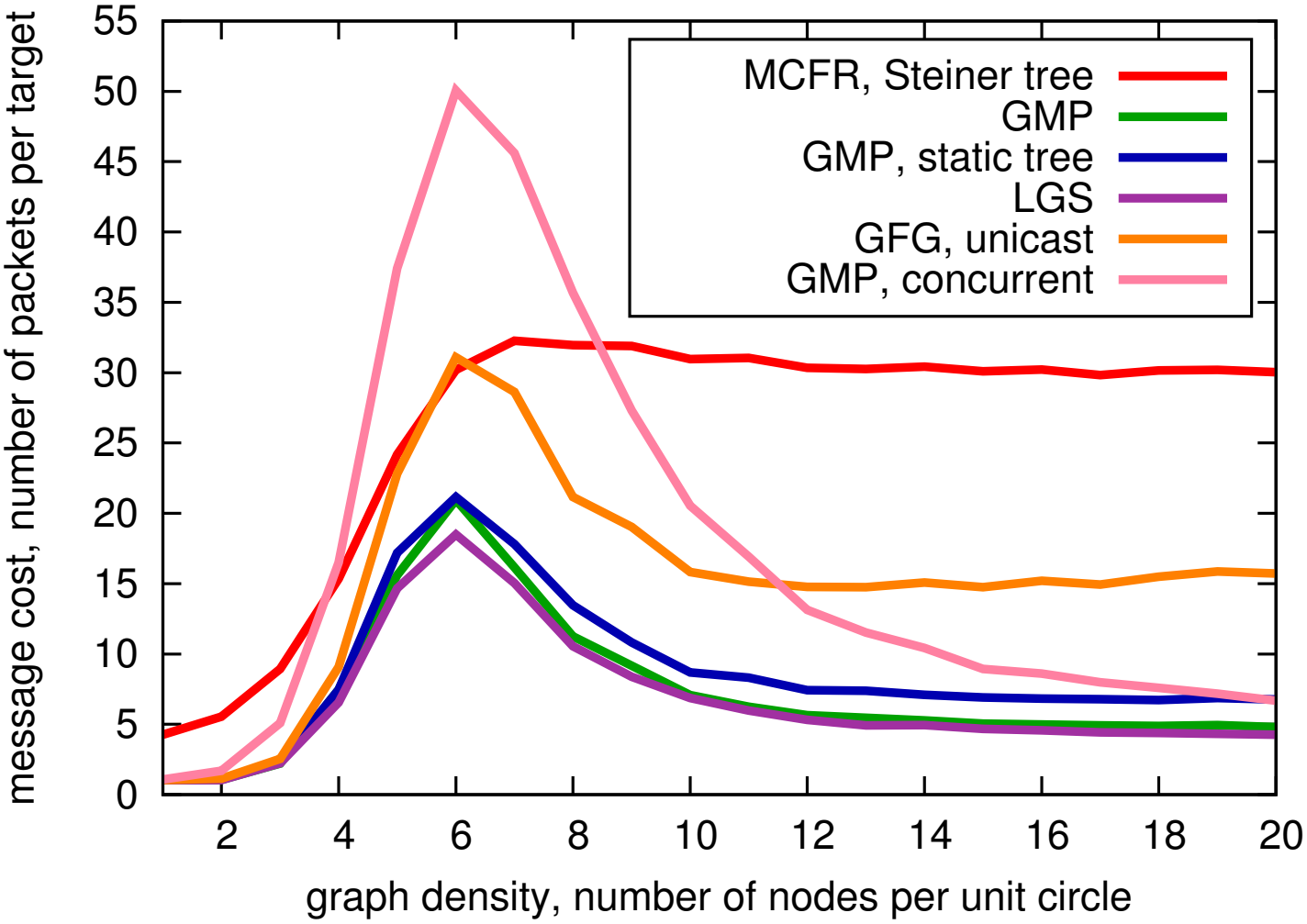
Abstract vs. Concrete Simulation

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

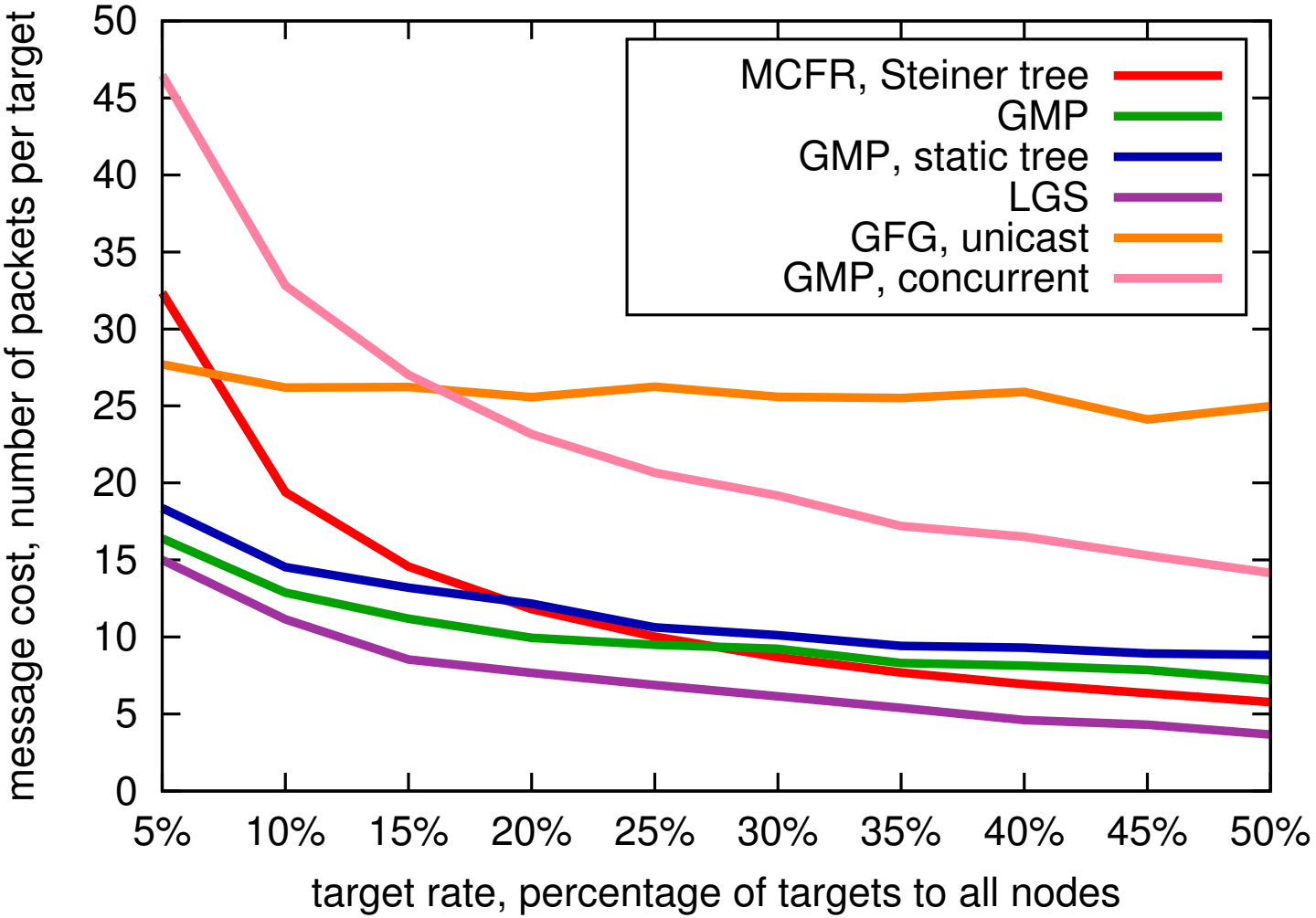
Abstract vs. Concrete Simulation

- **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
    IEEE 802.15.4, 866 MHz, BPSK, cst. path loss, Rayleigh fading
  - Practical performance aspects

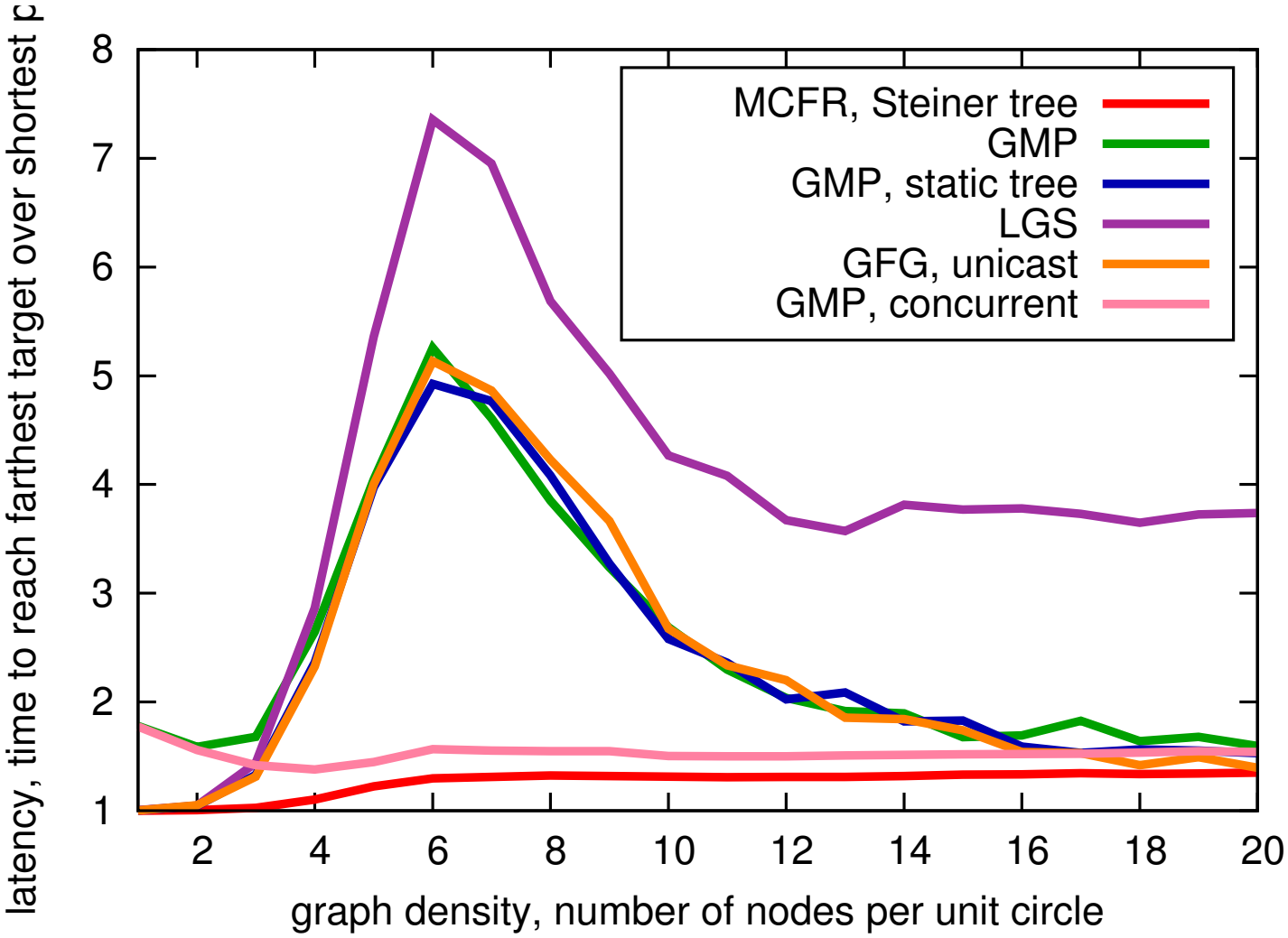
Abstract: Overhead by Density



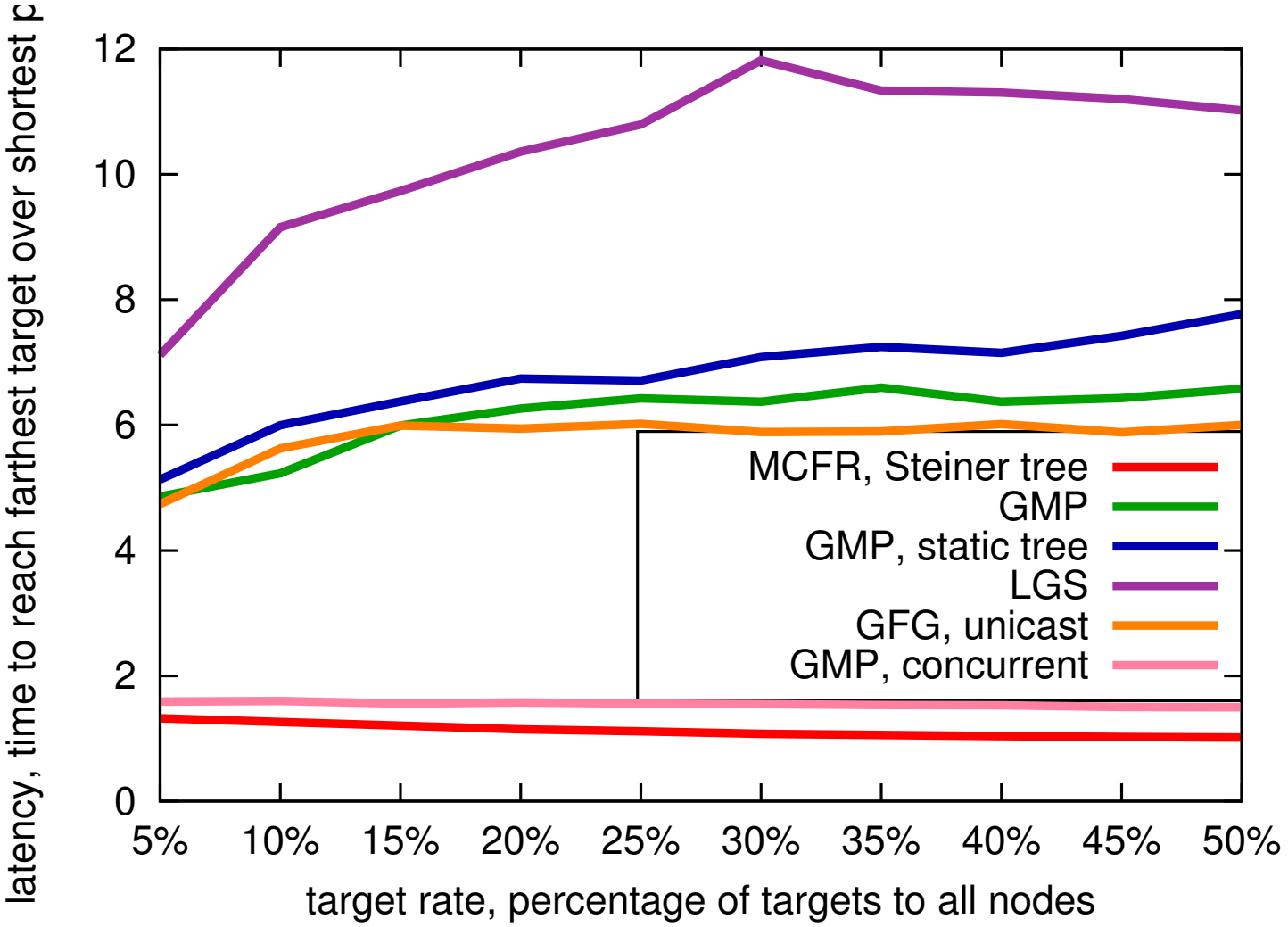
Abstract: Overhead by Target Rate



Abstract: Latency By Density



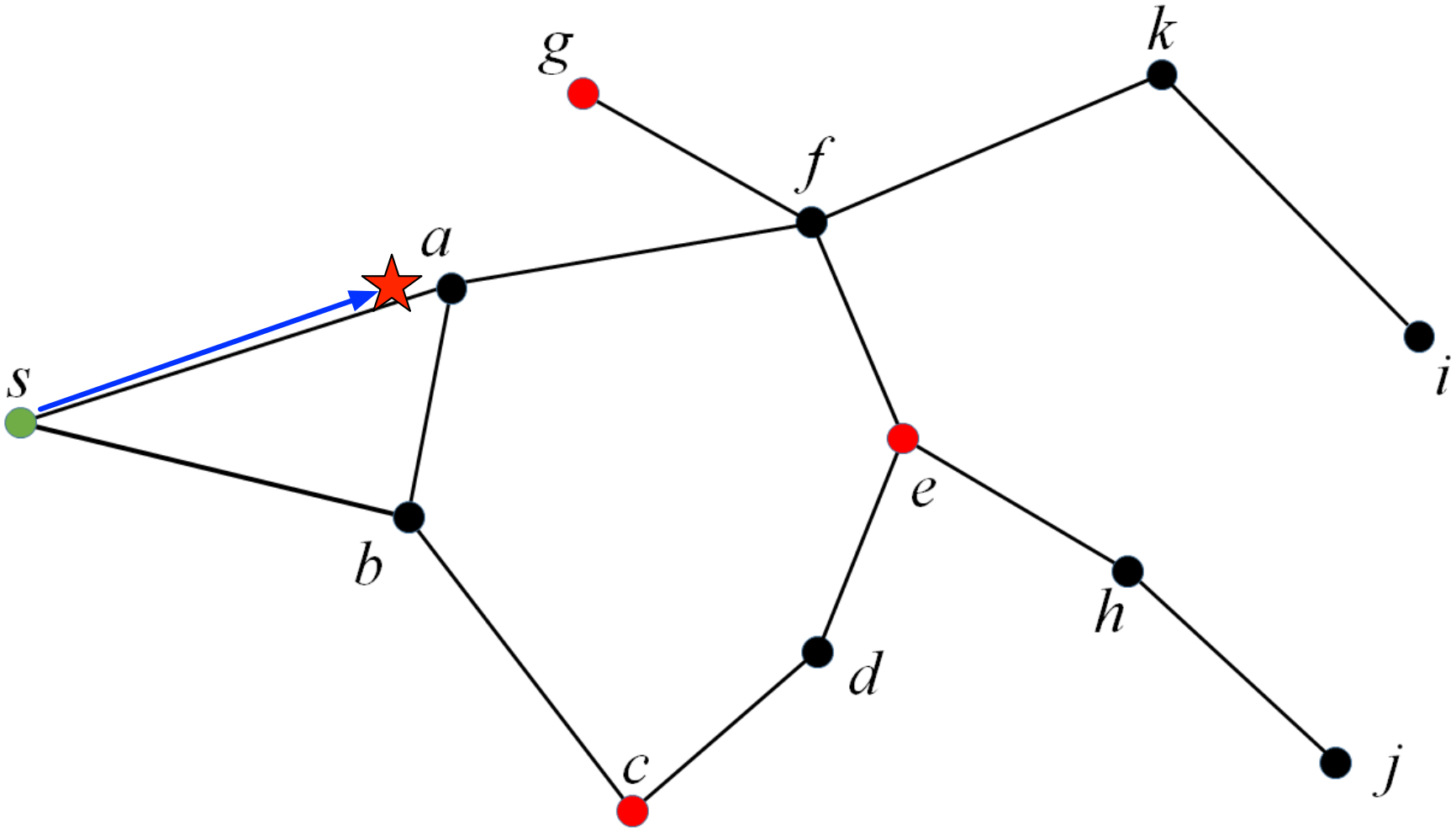
Abstract: Latency by Target Rate



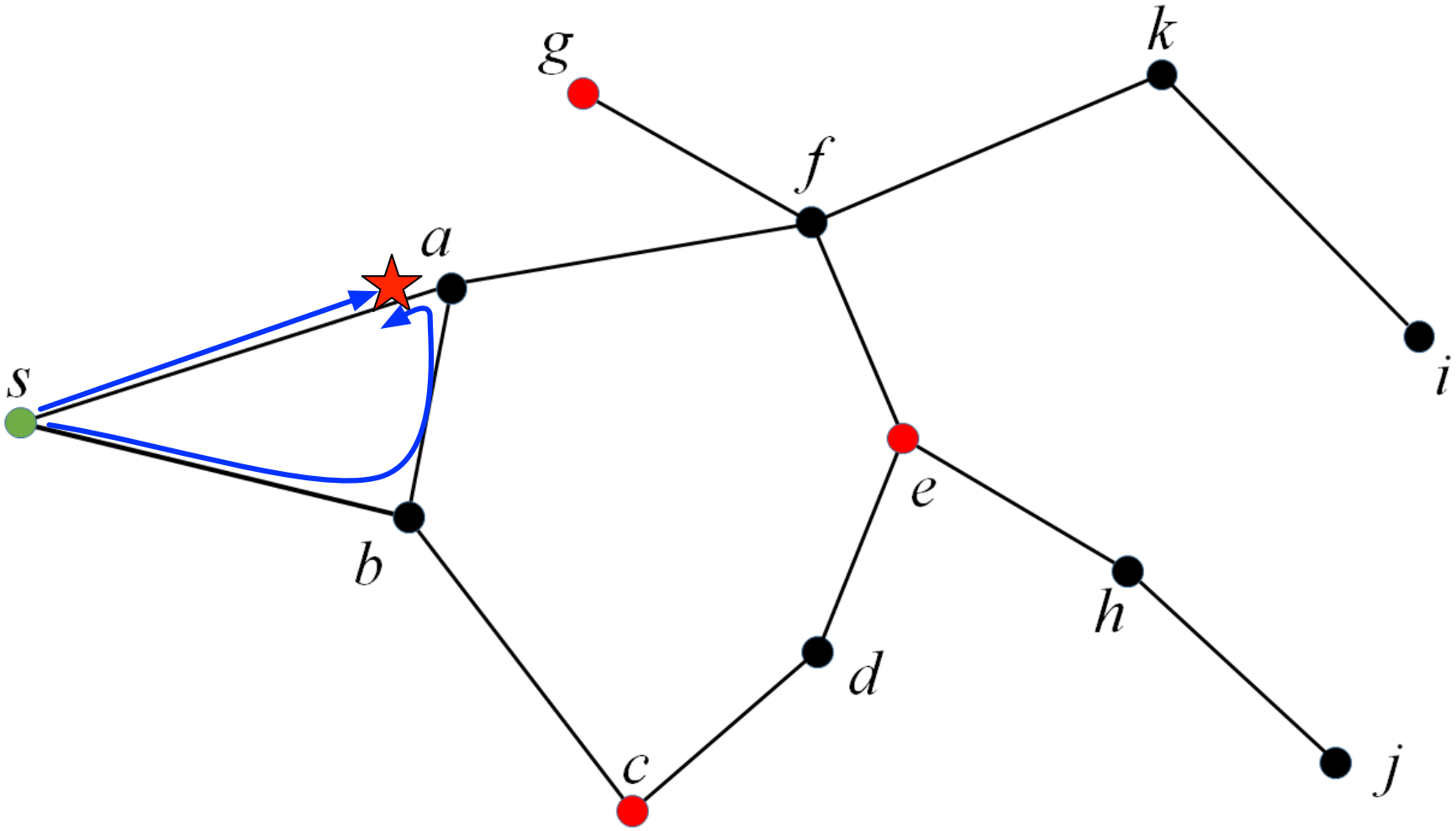
Abstract: Analysis

- **Tradeoff**: *message cost* (x2) vs. *latency* (x3-5)
- Concurrent approaches have lower latency
- Sequential approaches have lower message cost

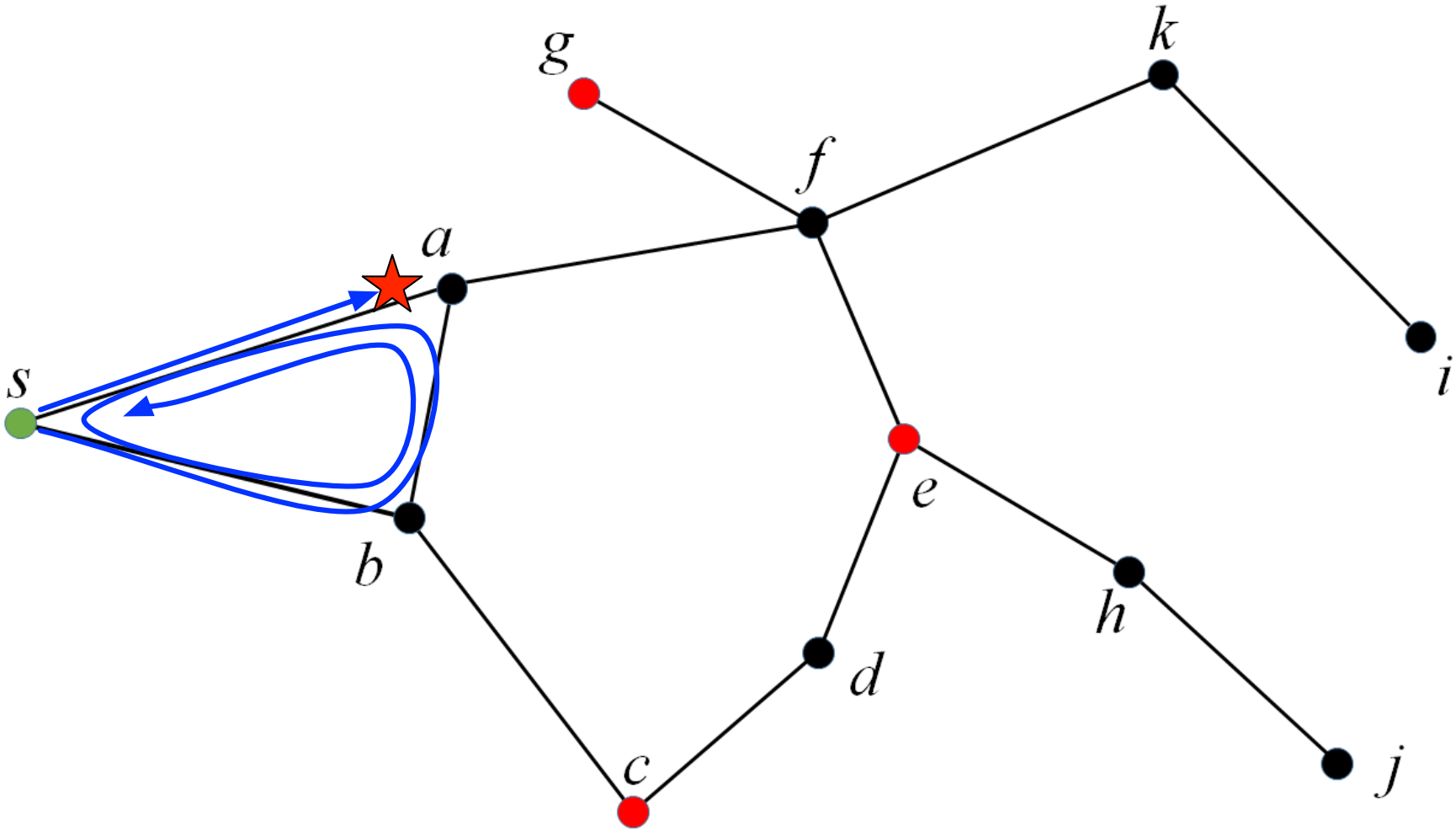
Concrete Experiments



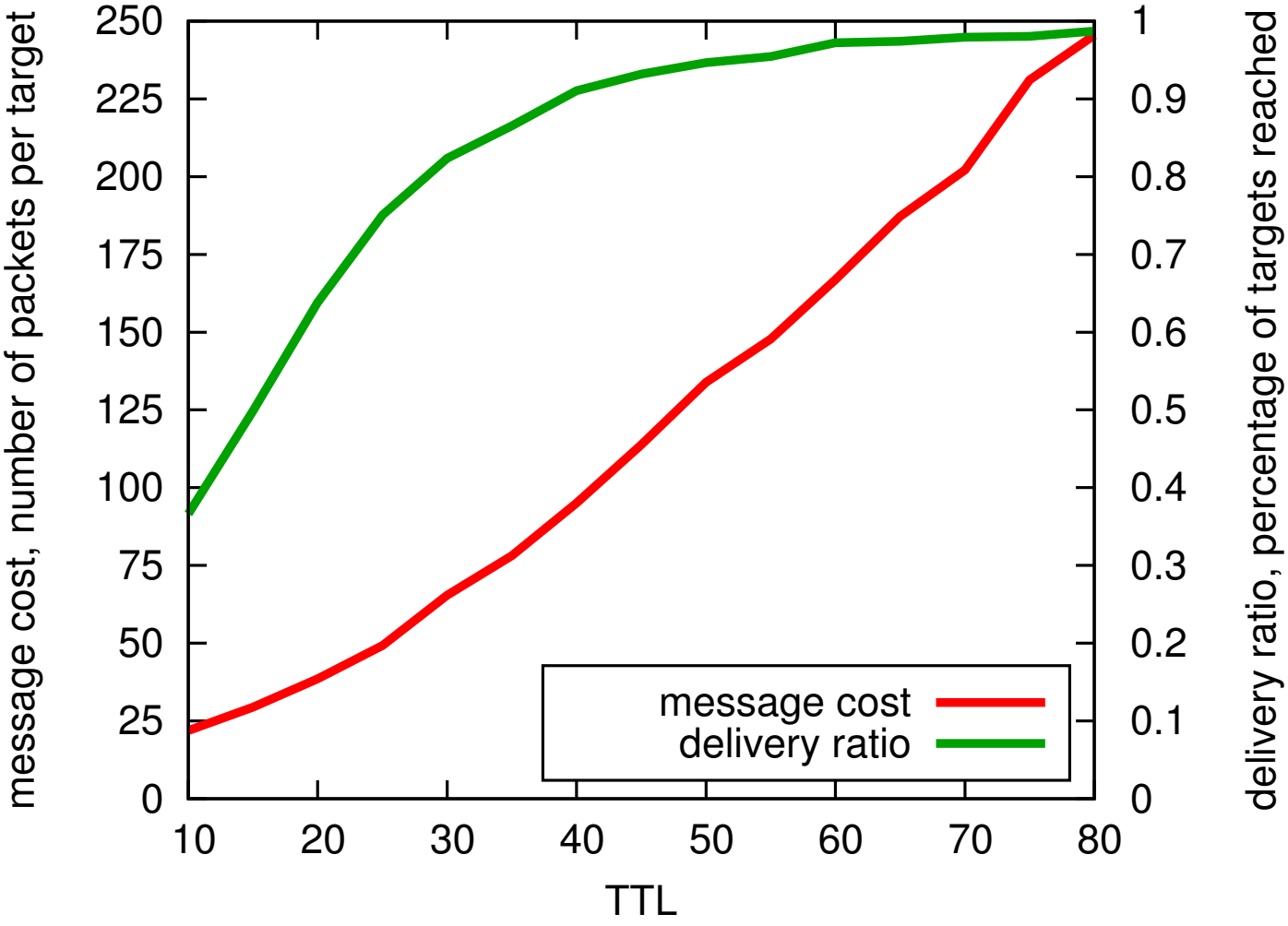
Concrete Experiments



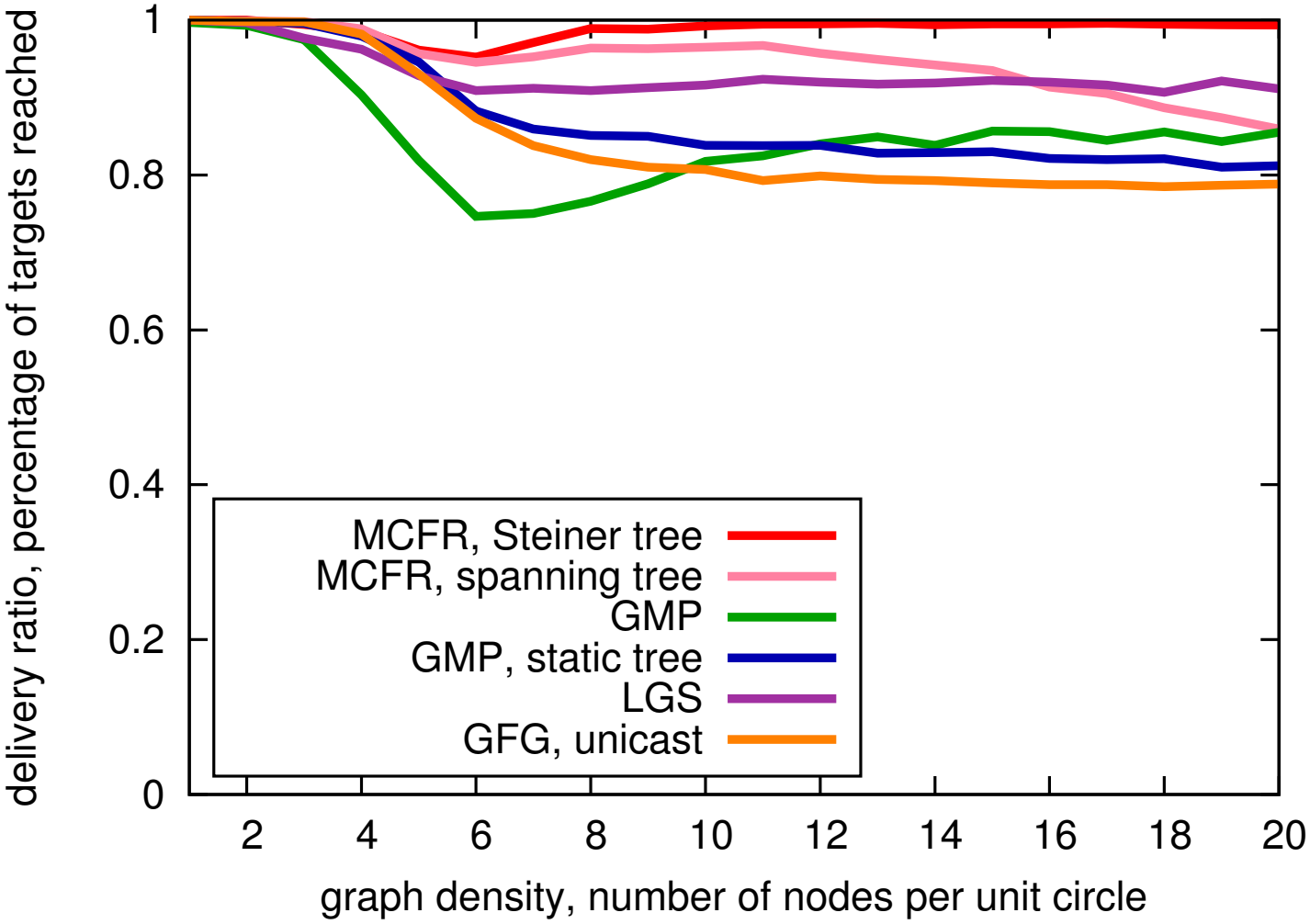
Concrete Experiments



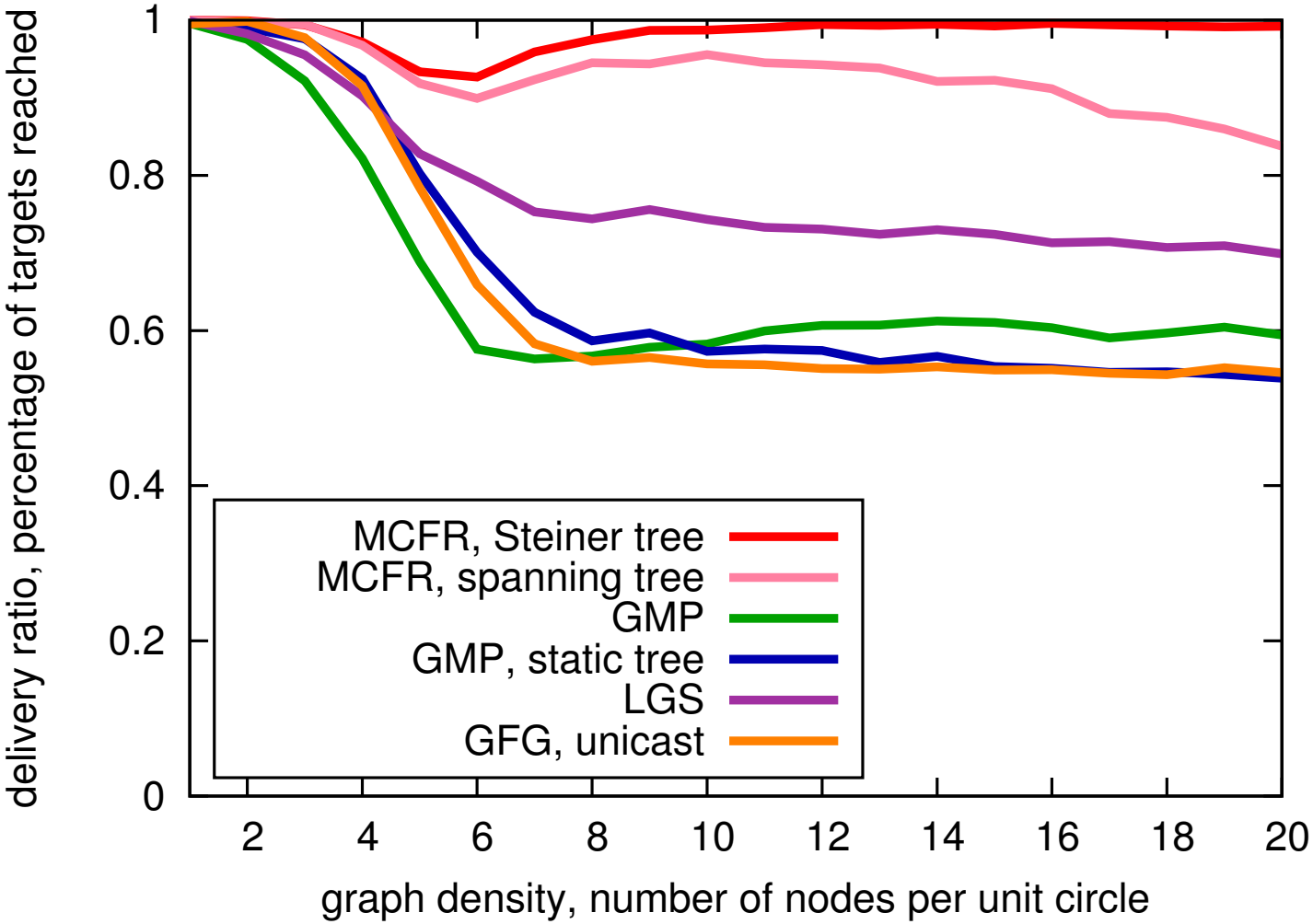
Concrete: TTL



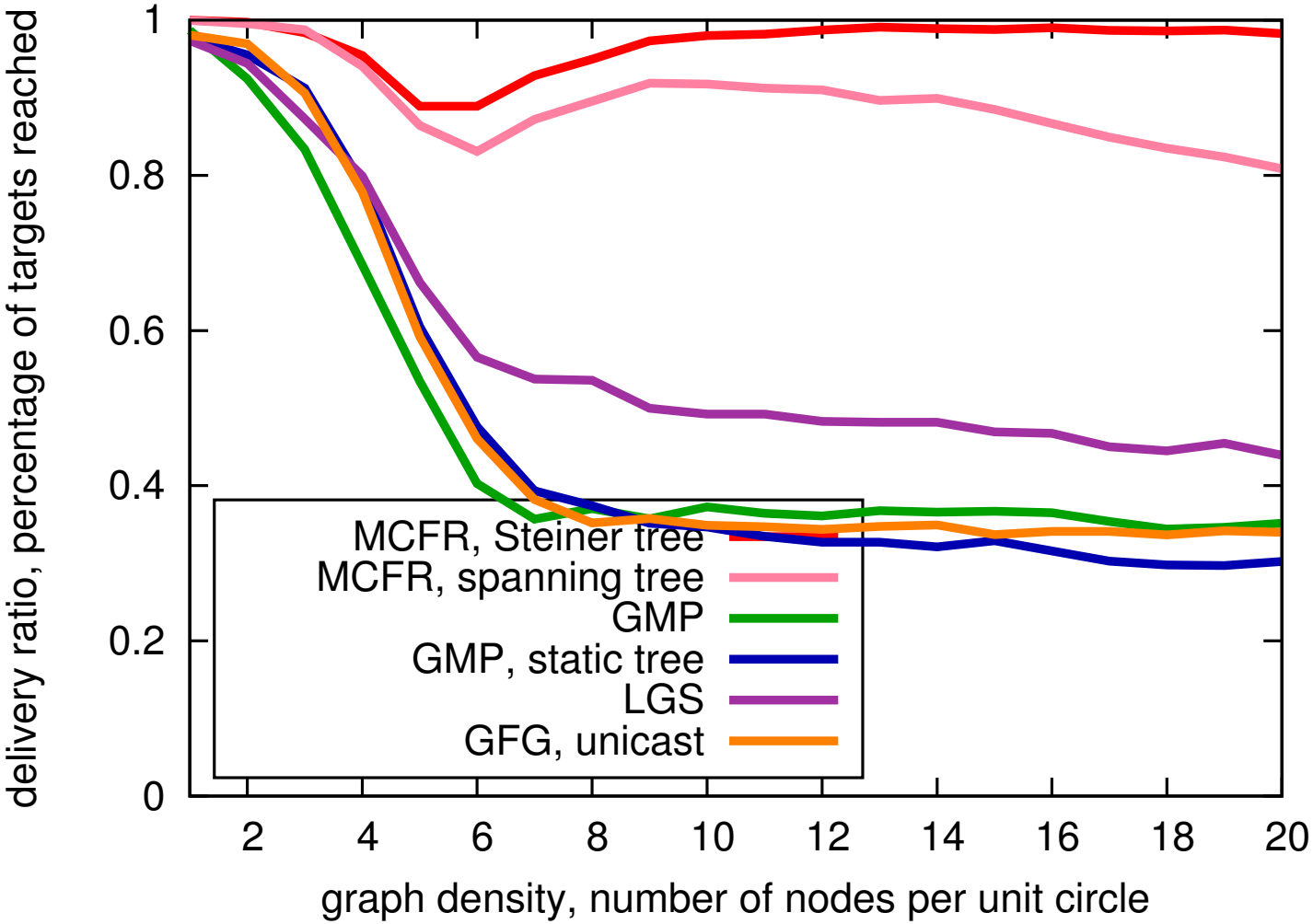
Concrete: Delivery Ratio 15dBm



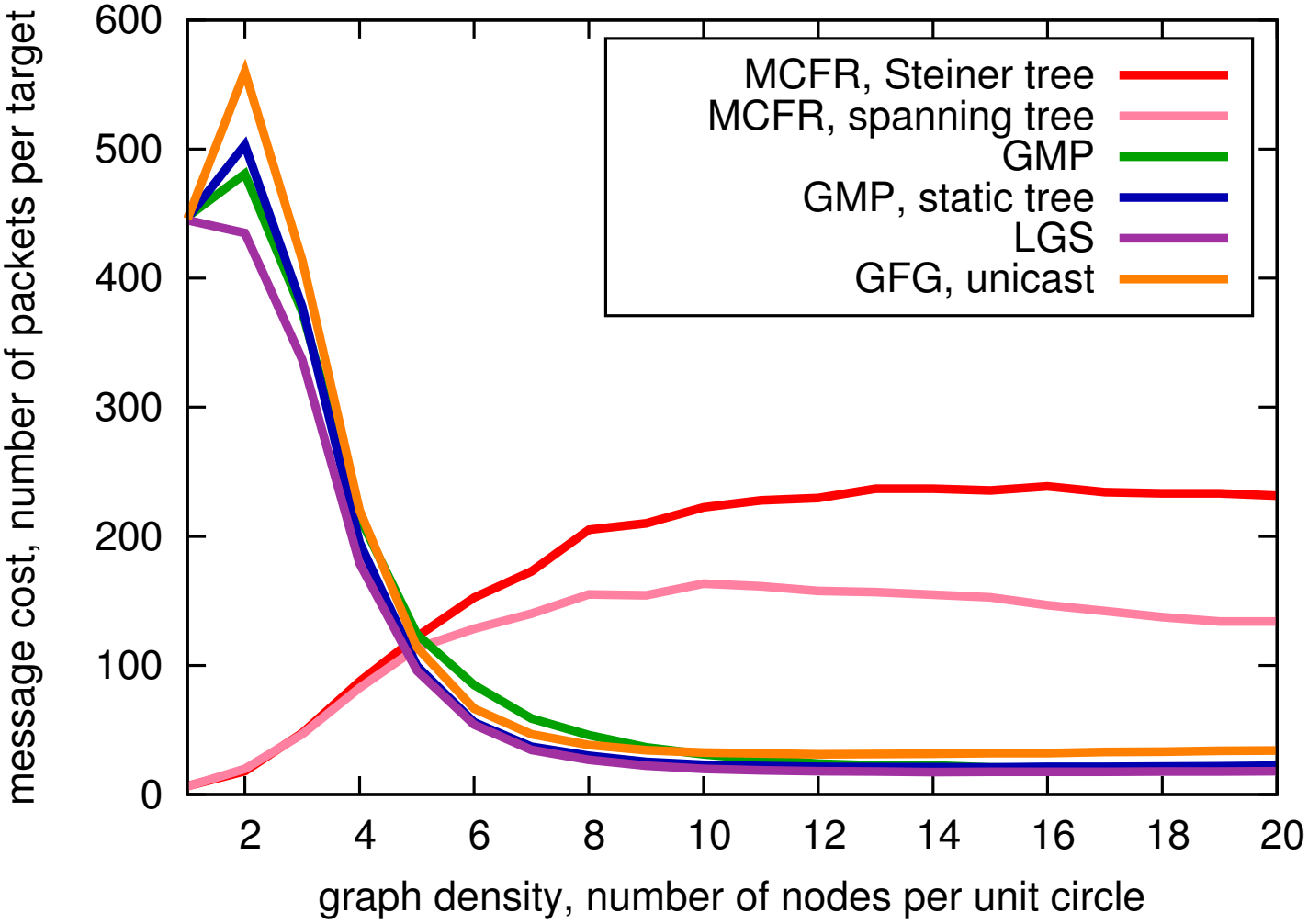
Concrete: Delivery Ratio 7dBm



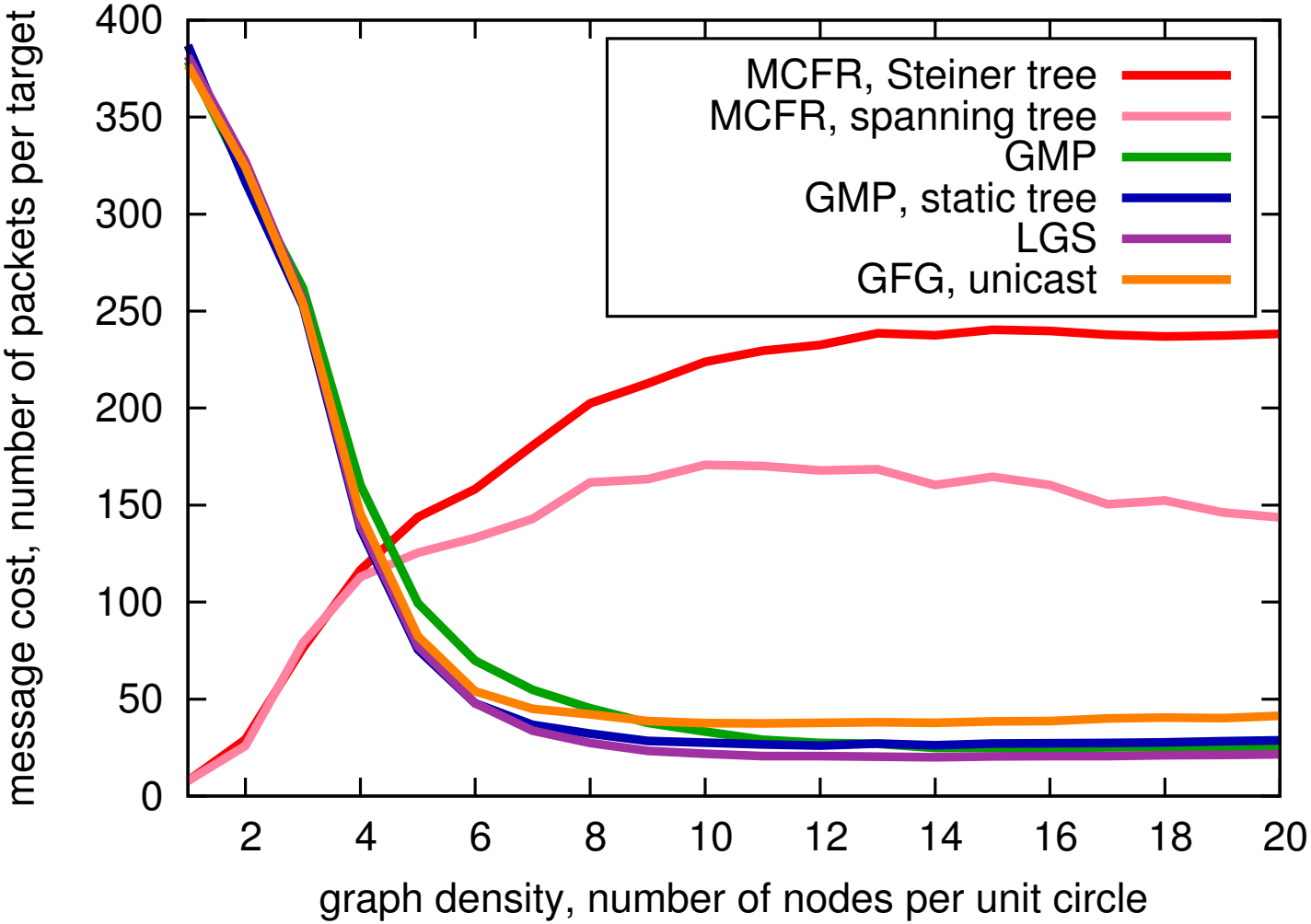
Concrete: Delivery Ratio 0dBm



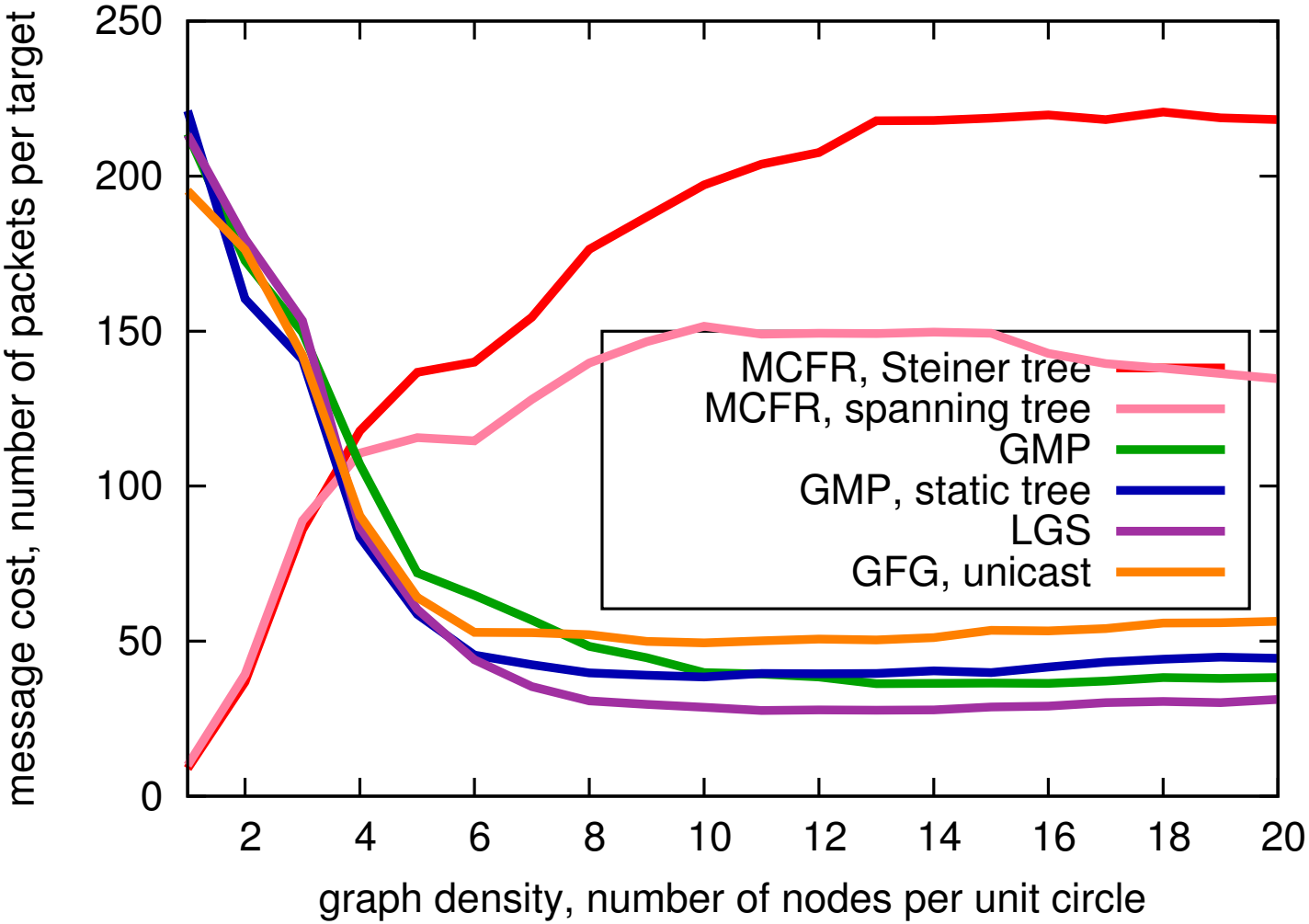
Concrete: Overhead 15dBm



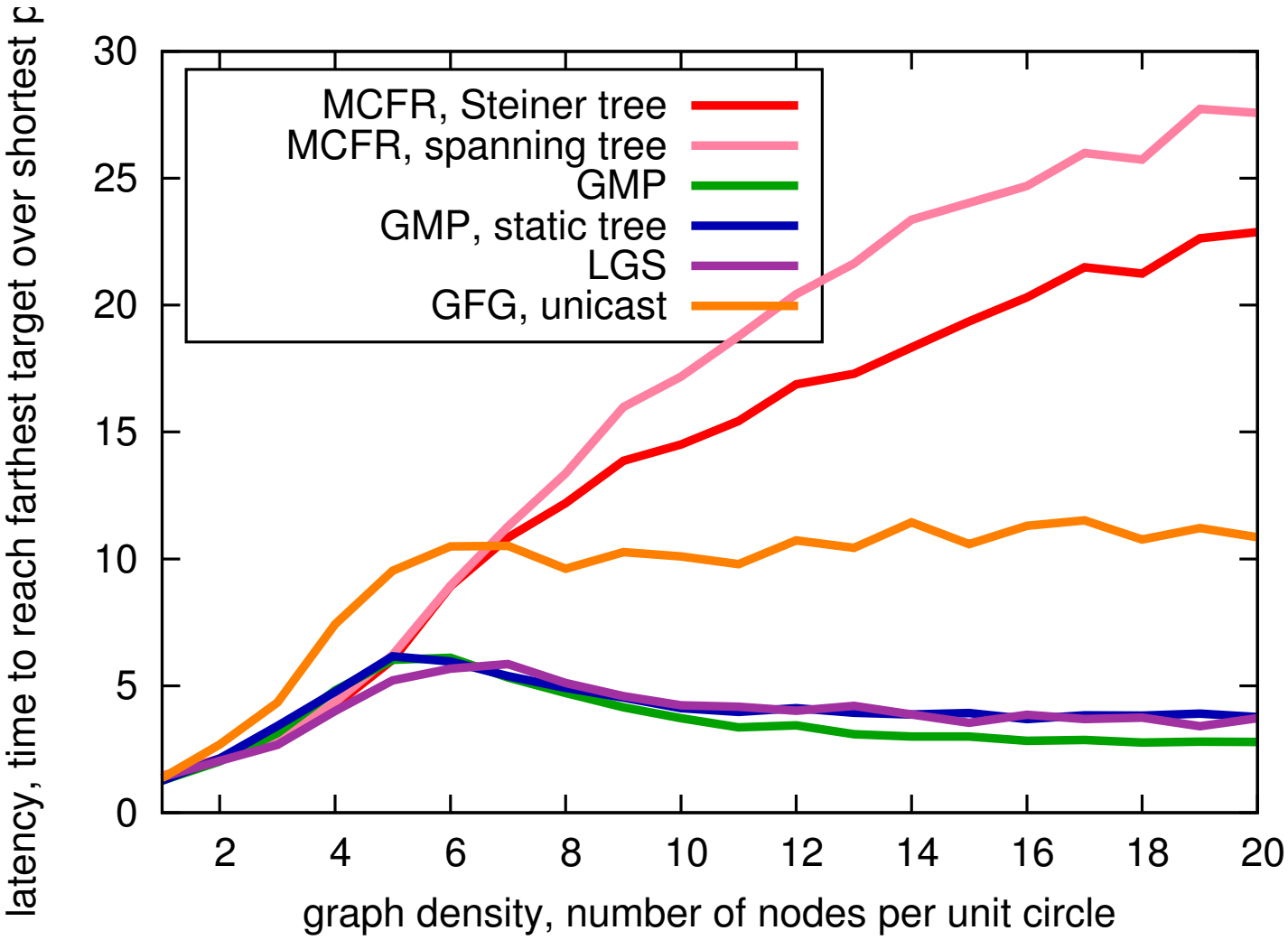
Concrete: Overhead 7dBm



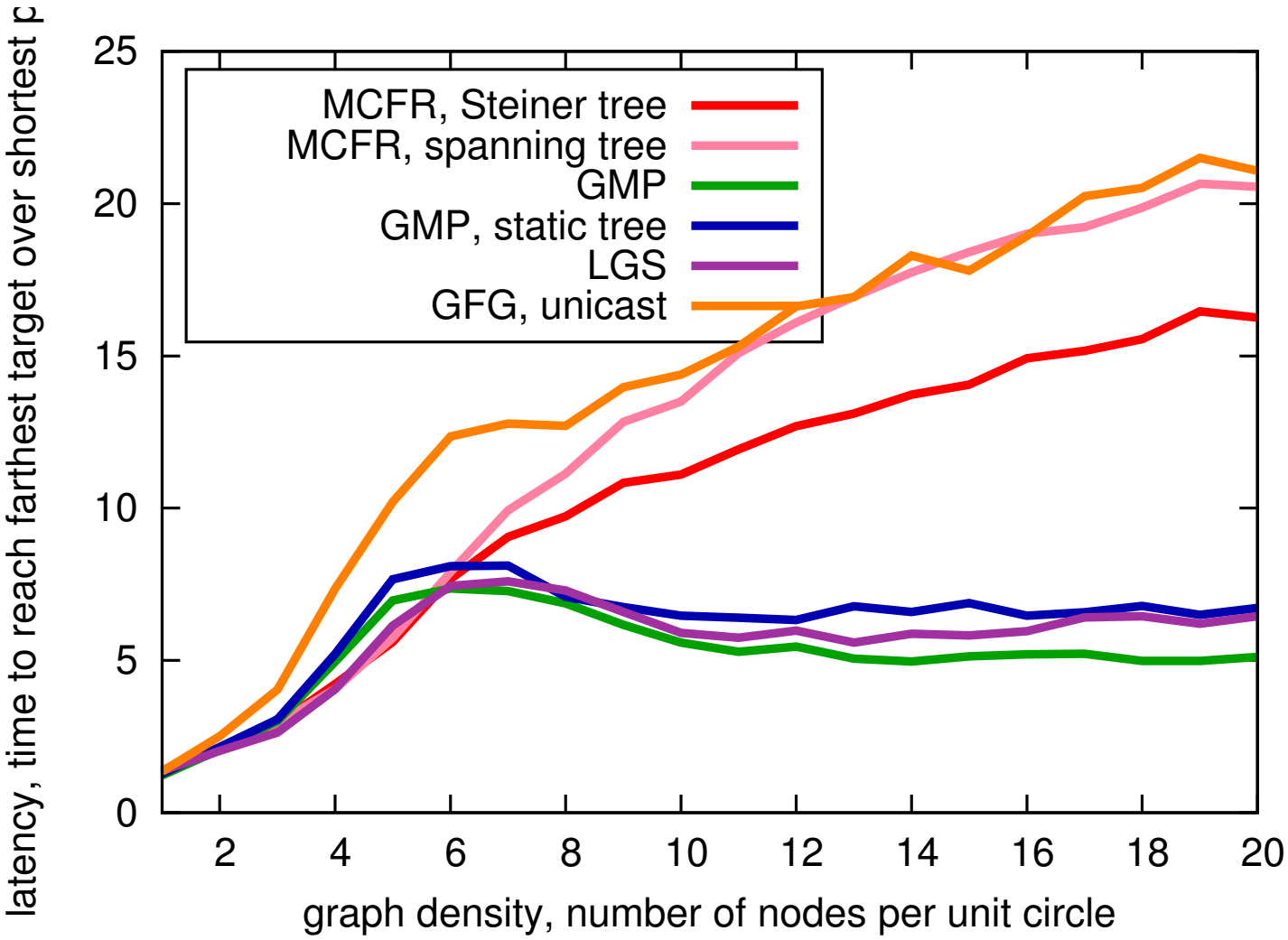
Concrete: Overhead 0dBm



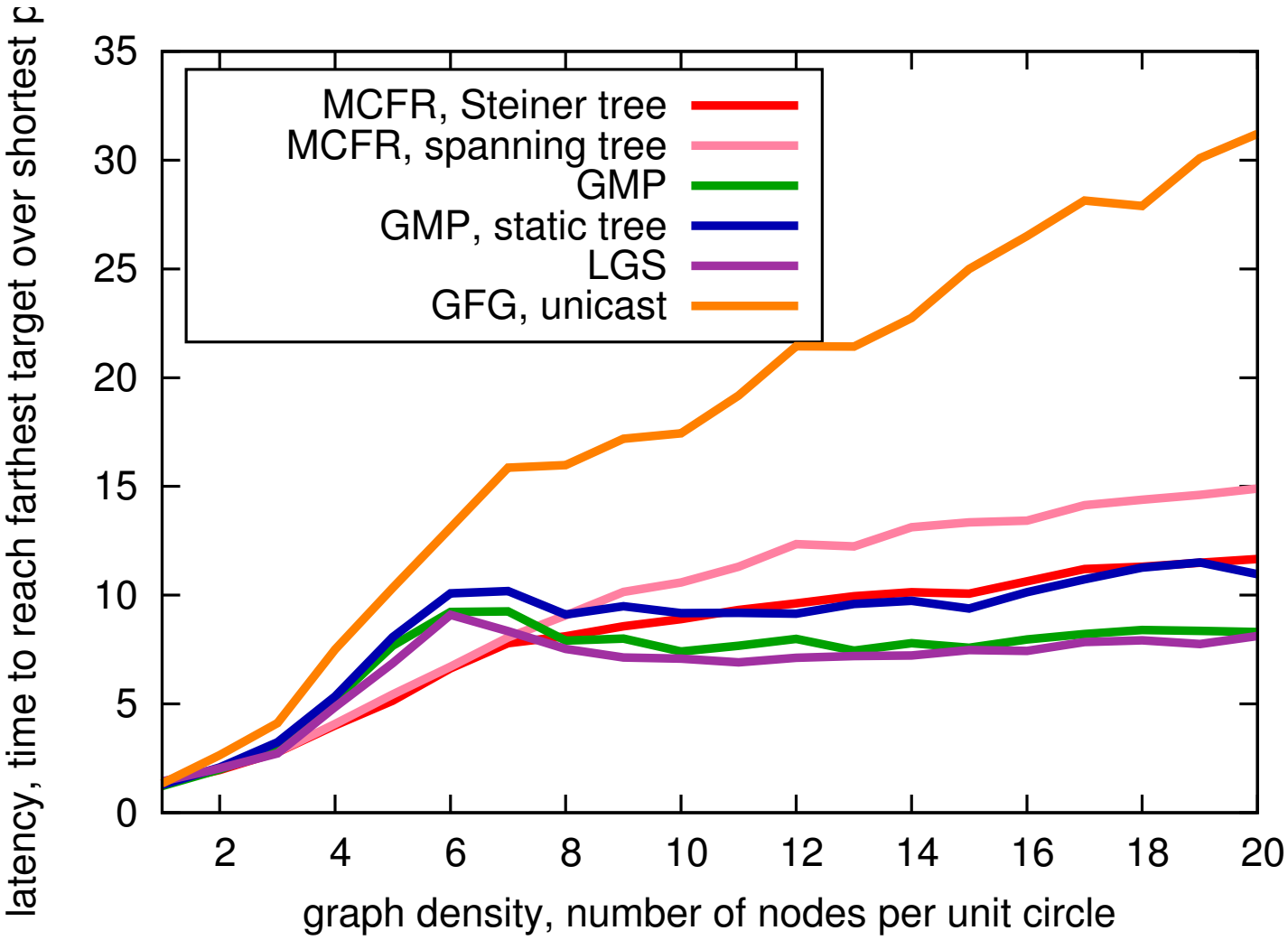
Concrete: Latency 15dBm



Concrete: Latency 7dBm



Concrete: Latency 0dBm



Concrete: Analysis

- Concurrent approaches are up to **more than twice as reliable** (90%+ delivery vs. 40%).
- Sequential approaches exhibit **more overhead** as transmitting **power increases** with low density.
- Concurrent approaches show **lower latency** as transmitting **power decreases**.

Conclusion

- **Concurrent face routing** is an interesting building block for ad hoc multicasting
- Good theoretical latency
- Increased practical reliability
- Higher message cost
- Source code and data:

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

Thank You