Communication Efficiency in Self-stabilizing Silent Protocols

Stéphane Devismes, Toshimitsu Masuzawa,
Sébastien Tixeuil

Université Joseph Fourier, Grenoble, France
Osaka University, Japan
Université Pierre & Marie Curie, France

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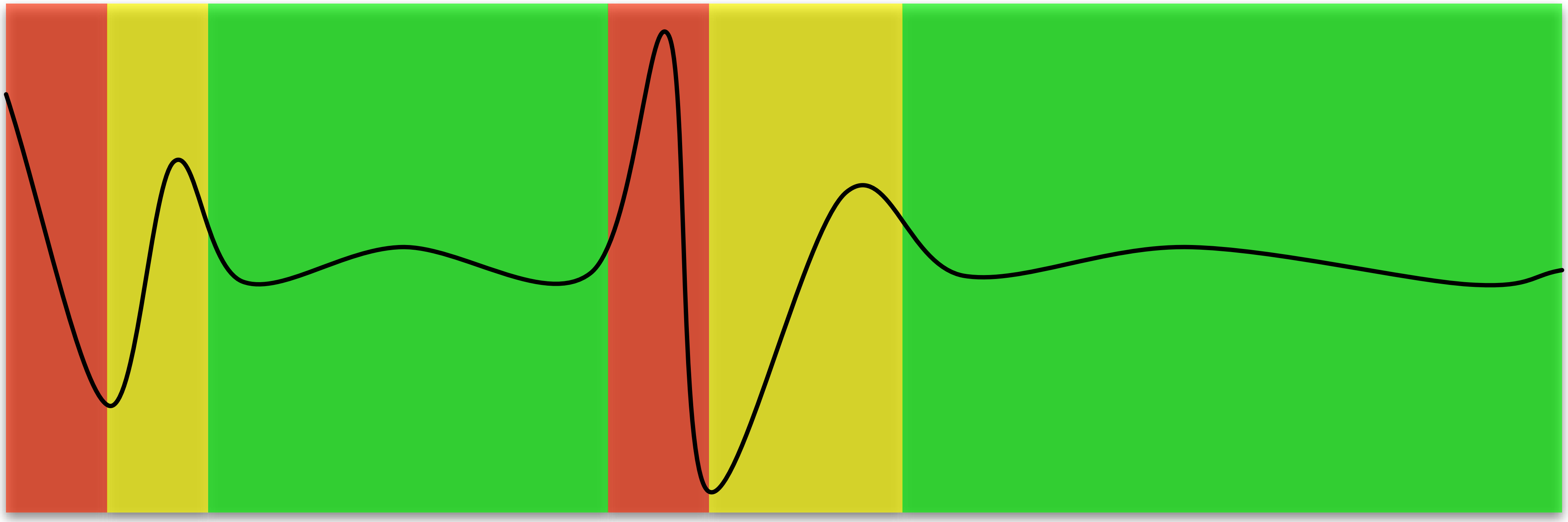
Self-stabilization



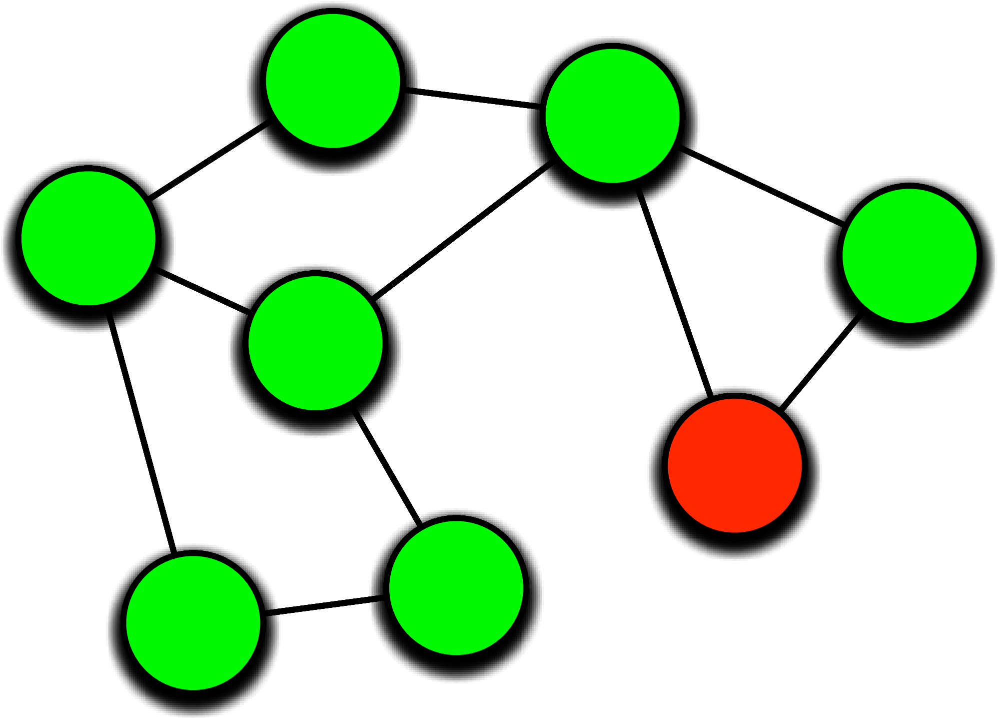
Overhead ?

- *Katz, Perry*. Self-stabilizing Extensions for Message Passing Systems. Distributed Computing, 1993.
- *Beauquier, Delaët, Dolev, Tixeuil*. Transient Fault Detectors. Distributed Computing, 2007.
- *Awerbuch, Patt-Shamir, Varghese*. Self-stabilization by Local Checking and Correction. FOCS, 1991.

Rationale

- Checking (eventually) **no** neighbor trivially **prevents** self-stabilization
- Checking **all** neighbors **forever enables** self-stabilization
- Intermediate communication cost ?

Silent Protocols



Communication Efficiency

- *Larrea, Fernandez, Arevalo*. Optimal Implementation of the weakest failure detector for solving Consensus. SRDS 2000.
- *Aguilera, Delporte-Gallet, Fauconnier, Toueg*. On implementing Omega with weak reliability and synchrony assumptions. PODC 2003.

Results

- New measure for communication efficiency of self-stabilizing protocols
- **-** Neighbor-complete protocols can not be silent self-stabilizing and eventual-*k*-stable when degree > *k* (IDs and leader help slightly)
- **+** It is still possible to have *some* nodes check less that all neighbors for some

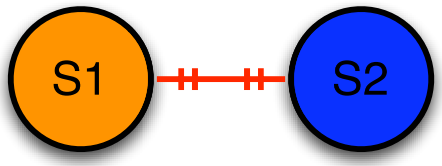
k-Efficiency

- **Definition**
  - A protocol is *k-efficient* if at any step, a node reads from at most k neighbors
- ***Intuition***
  - Round-Robin for neighbor checking
  - Local invariants may not be preserved

Communication Stability

- **k-stable**
  - In any *execution*, every node communicates with at most *k* *different* neighbors
- **eventual k-stable**
  - In any *execution*, every node *eventually* communicates with at most k *different* neighbors

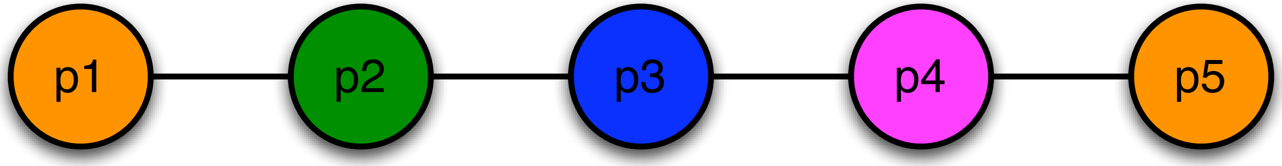
Neighbor Completeness

- **Definition**
  - A protocol is *neighbor complete* if it is
    - Self-stabilizing
    - Silent
    - States S1 and S2 can be legitimate
    - For every couple of neighbors 

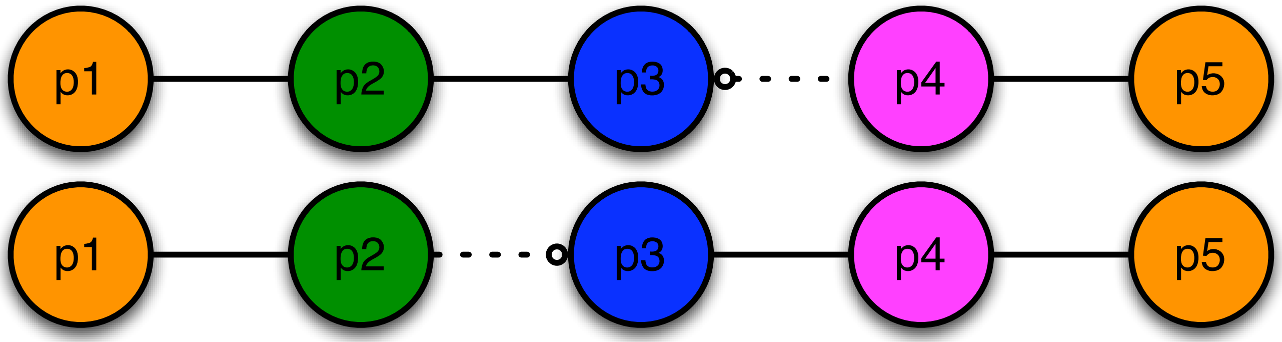
Impossibility I

- **Theorem**
  - There exists **no** eventual k-stable neighbor complete protocol in anonymous networks when degree > k

Impossibility I



Impossibility I



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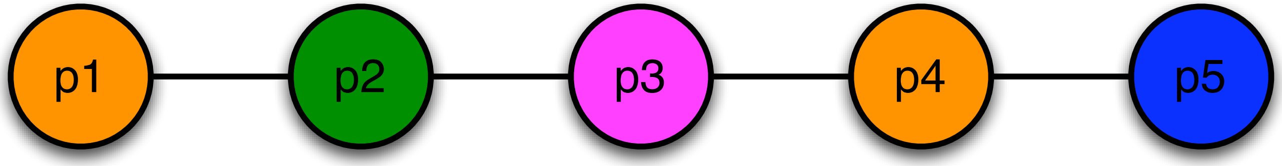

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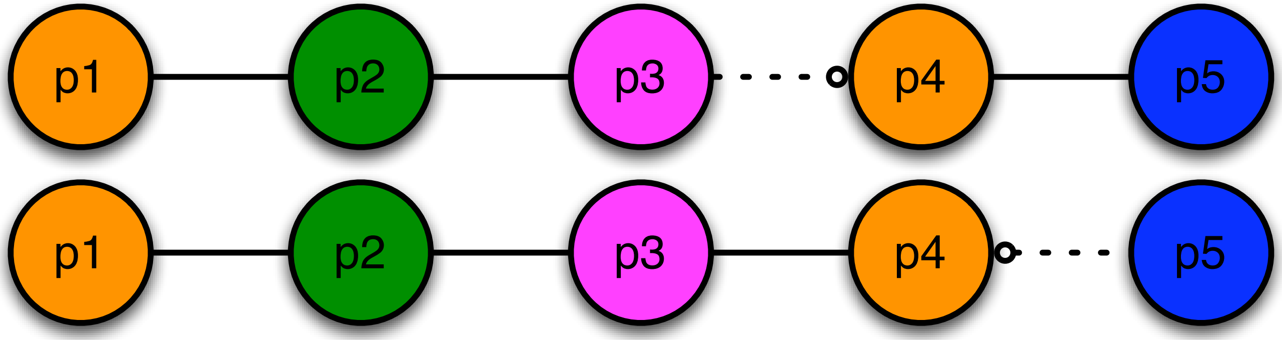

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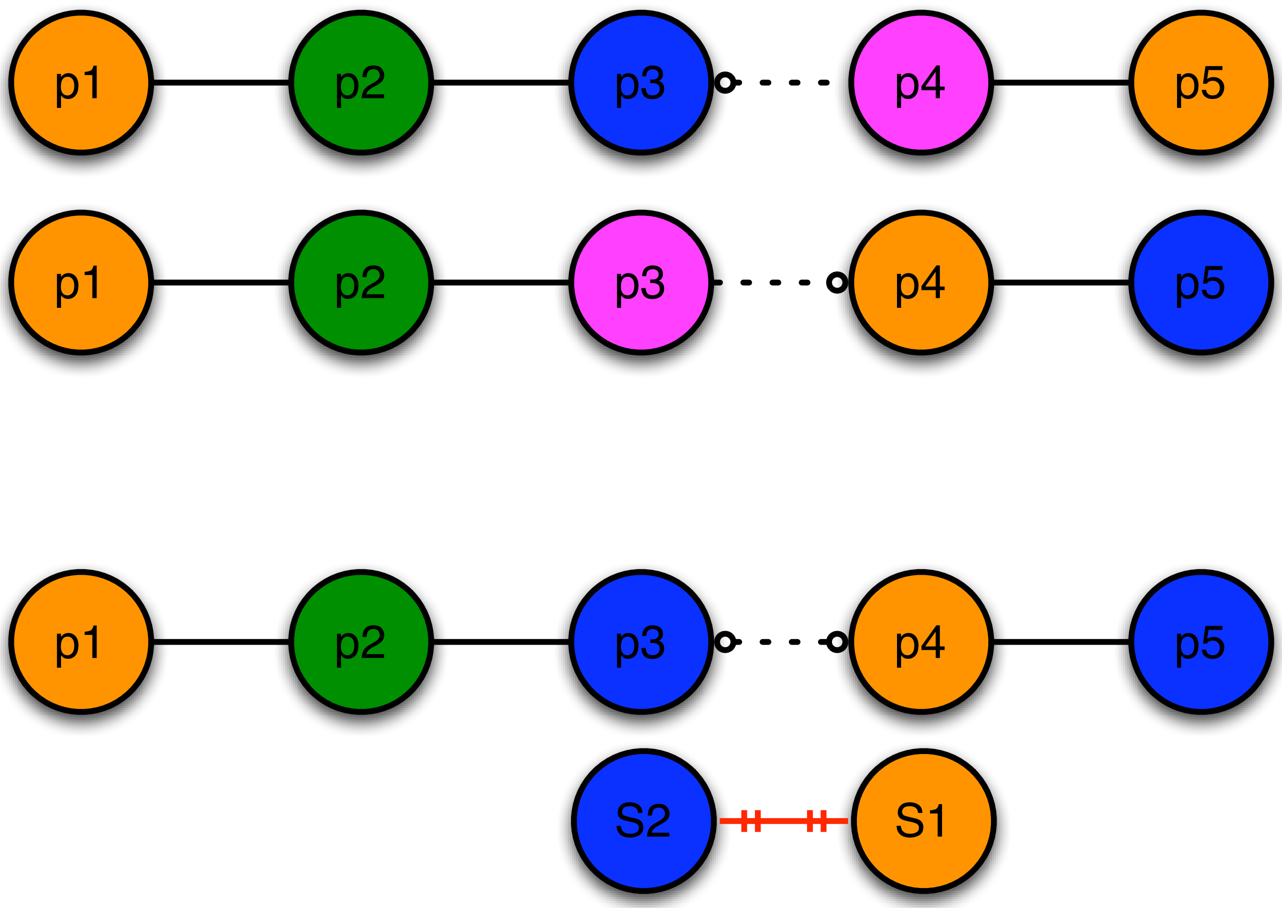

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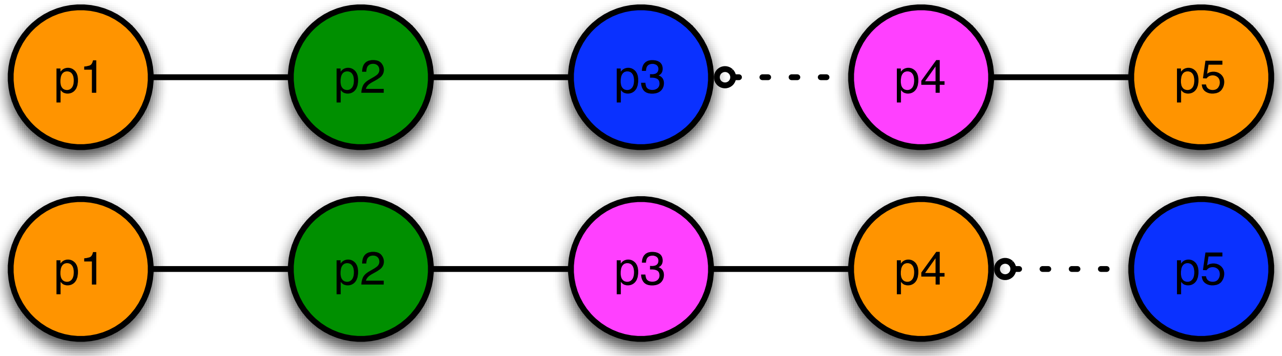

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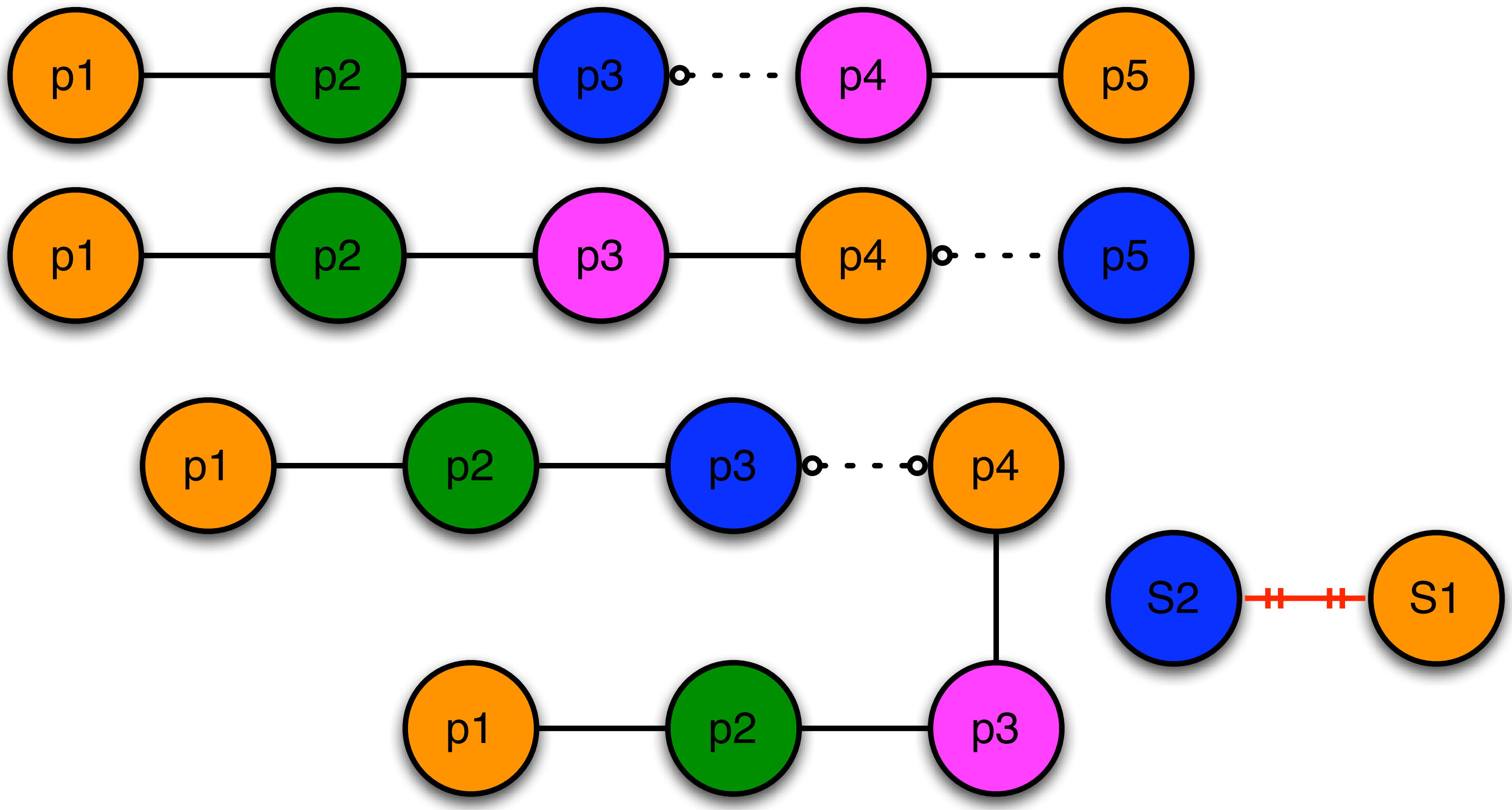
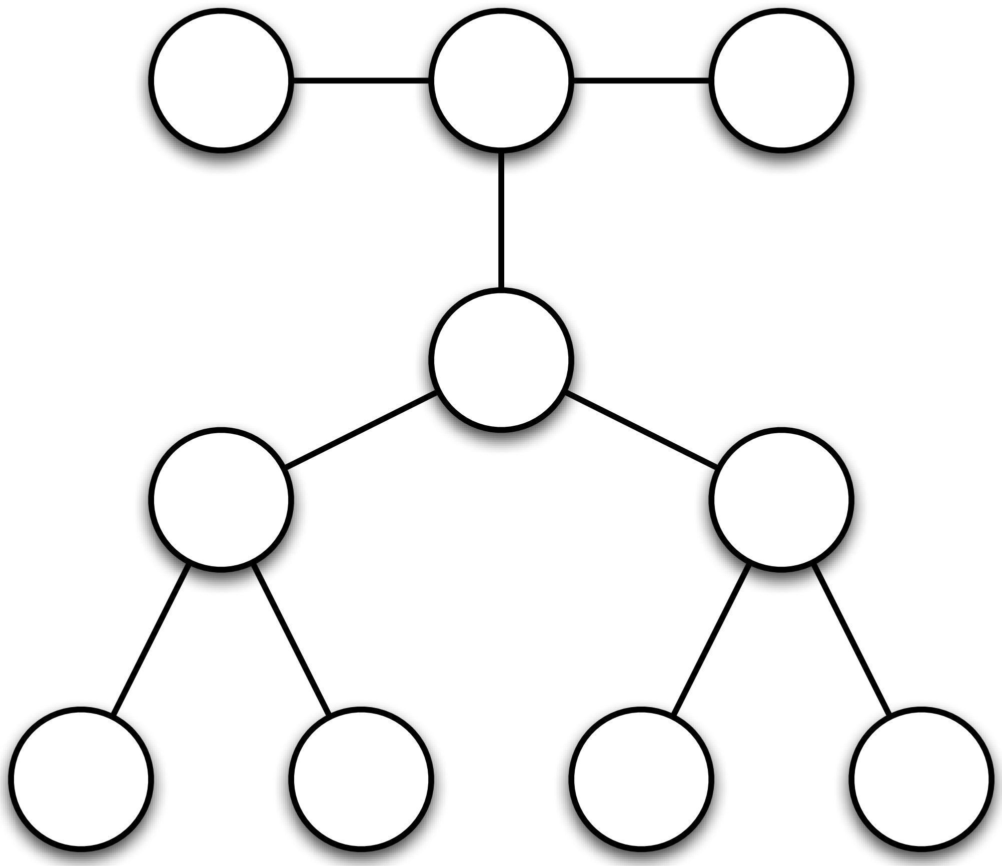


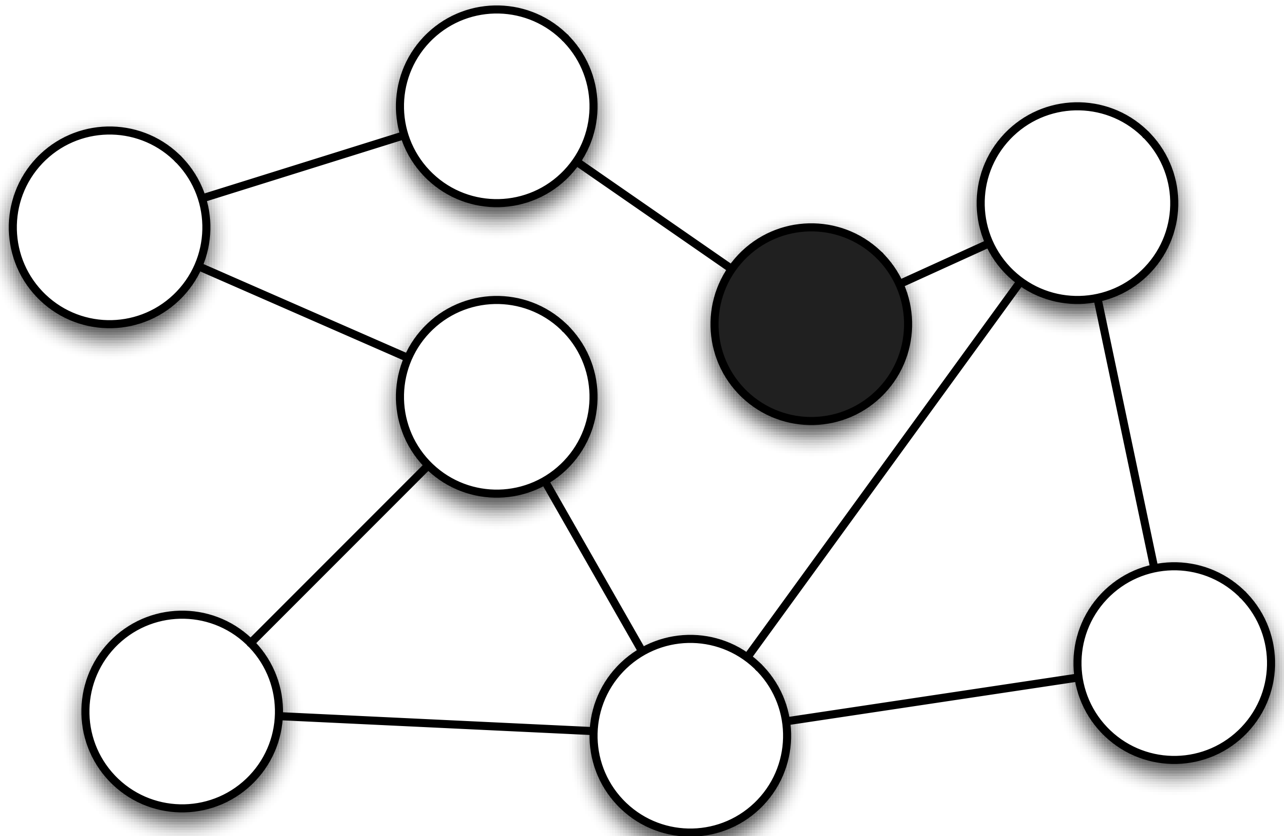
Impossibility I



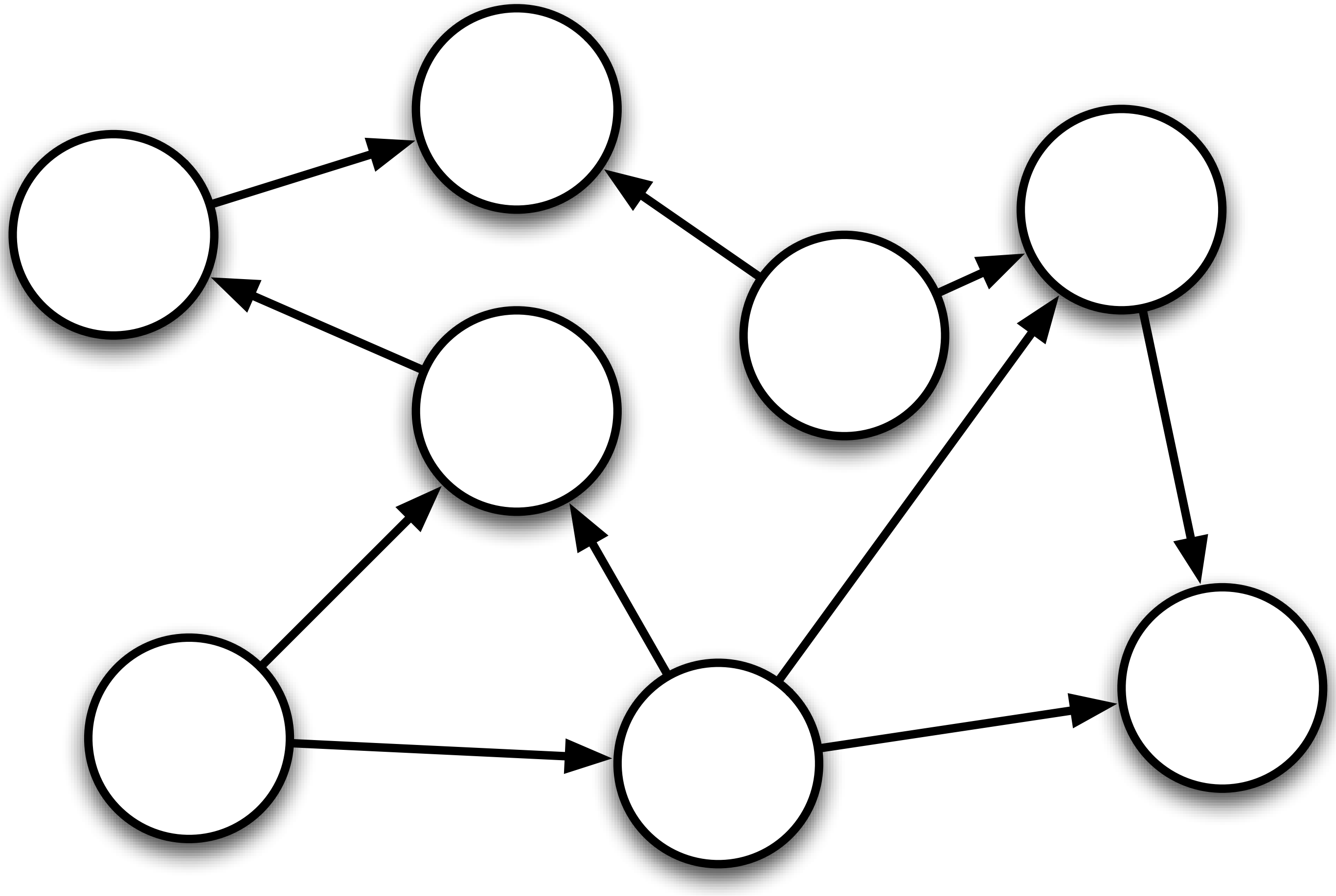
Impossibility II

- **Theorem**
  - There exists **no** k-stable neighbor complete protocol in *rooted and/or DAG-oriented* networks when degree > k

Rooted Networks



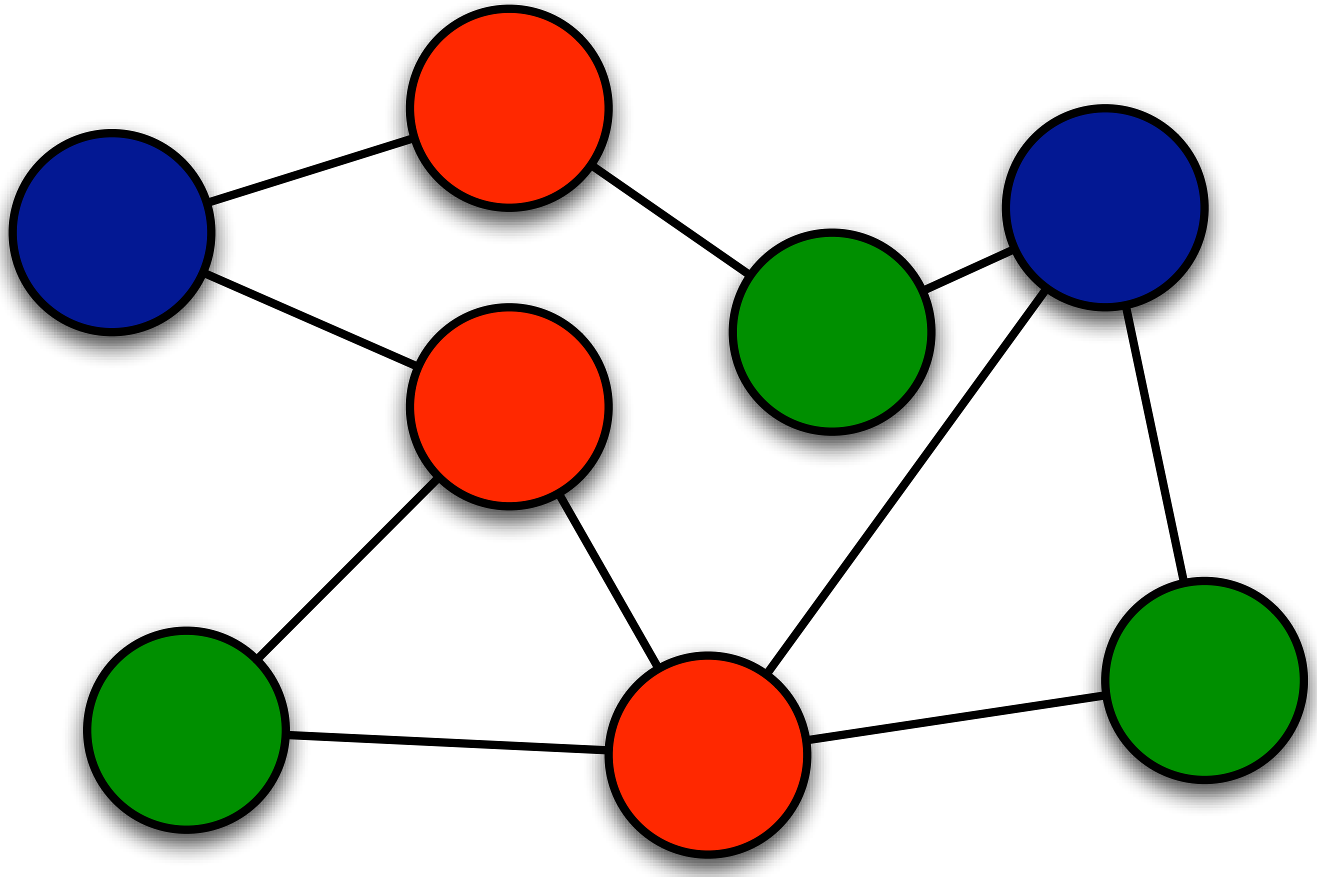
DAG-oriented Networks



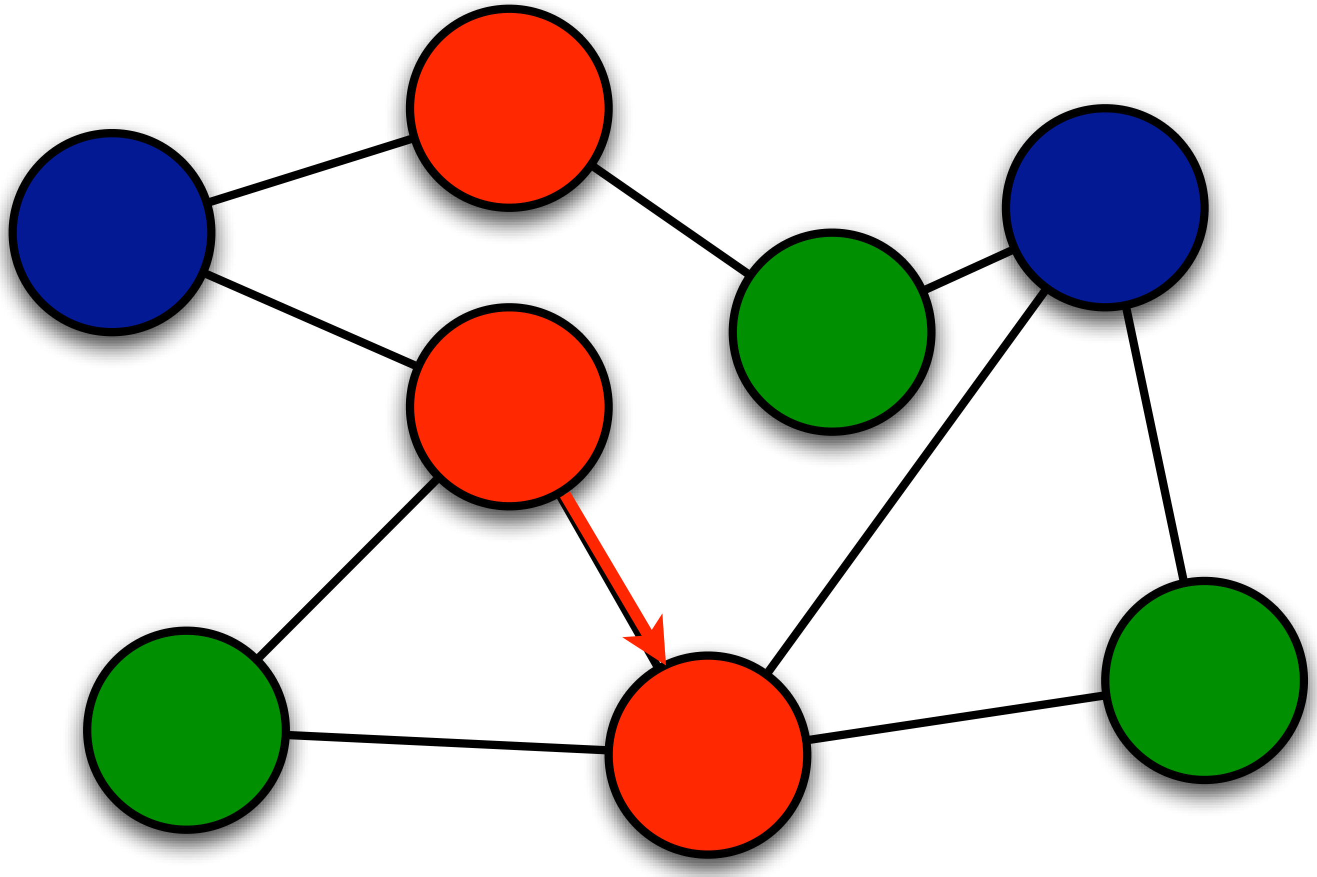
1-efficient Coloring

- Use Round-Robin technique to detect inconsistencies
- Color change may trigger *unknown* conflicts
    - *Bernard, Devismes, Potop-Butucaru, Tixeuil*, Optimal Deterministic Vertex Coloring in Unidirectional Anonymous Networks. IPDPS 2009.

Coloring



Coloring



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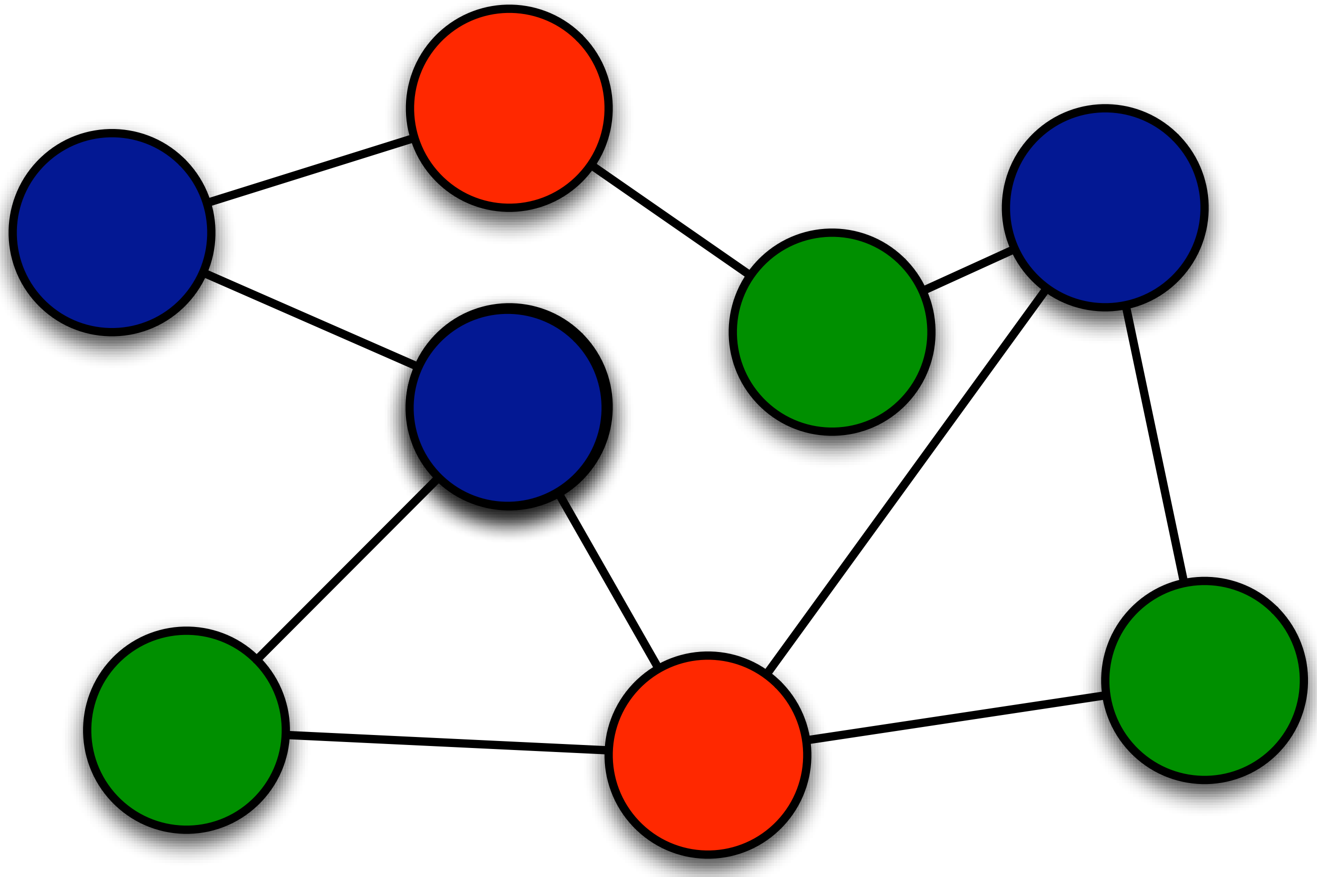

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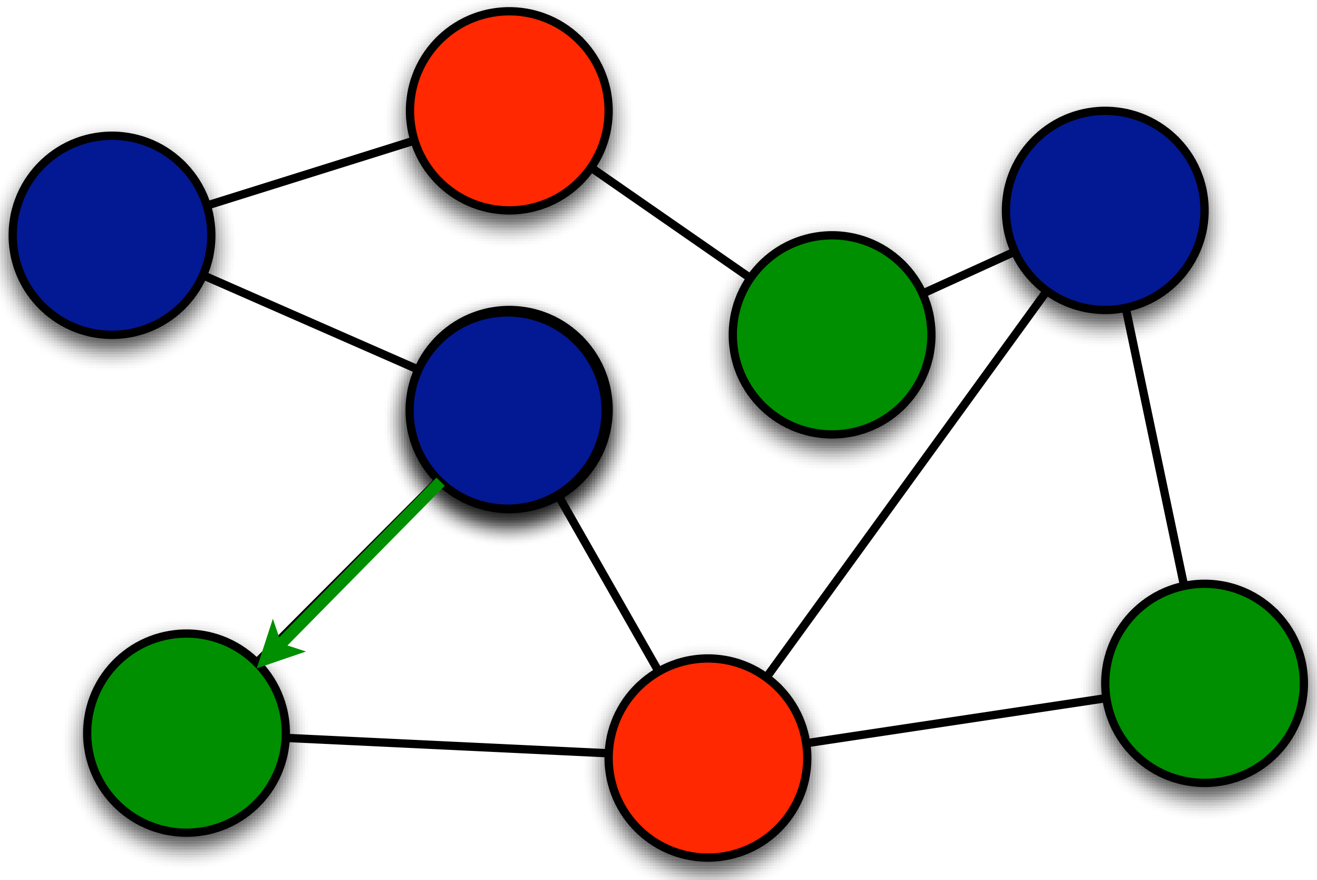

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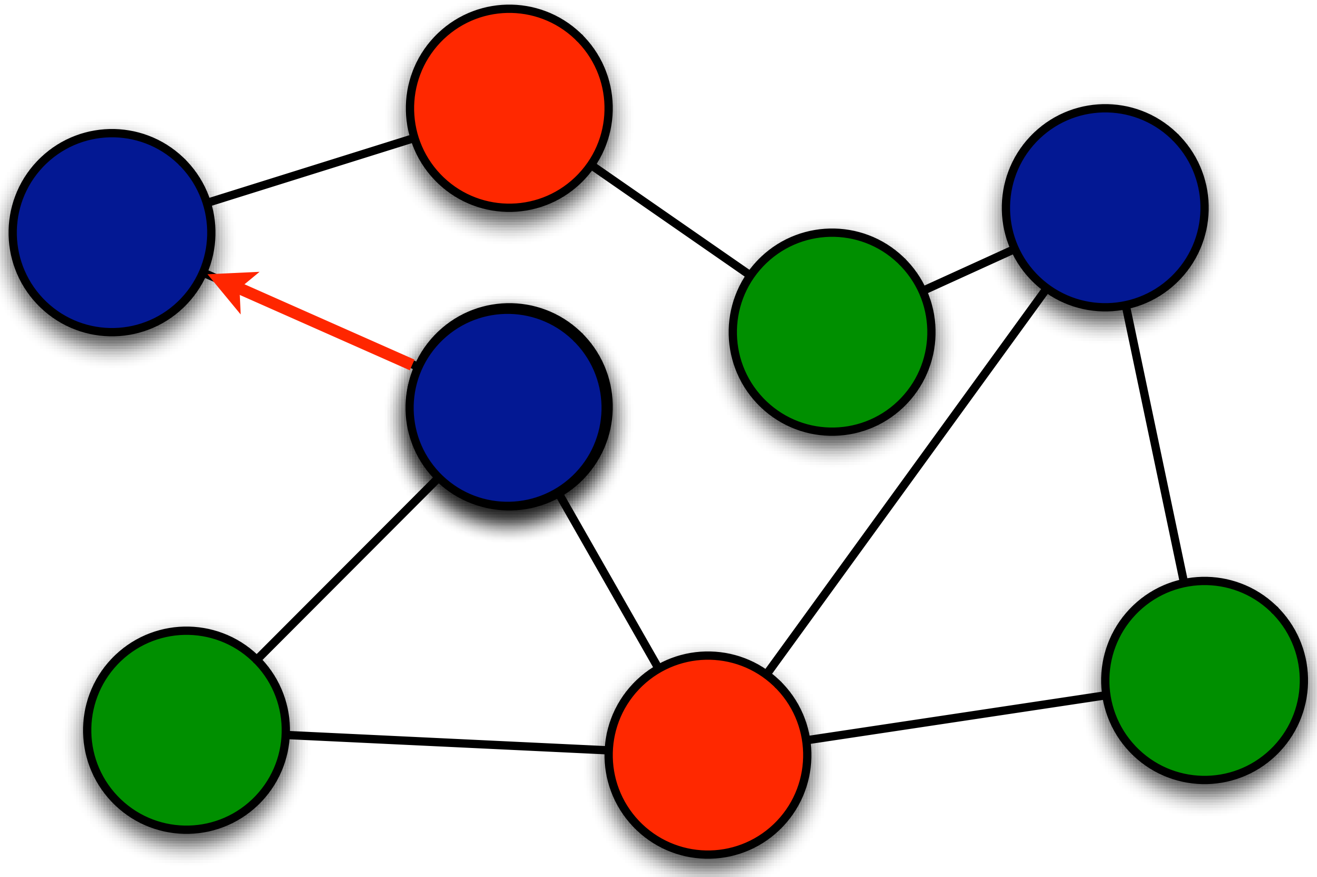

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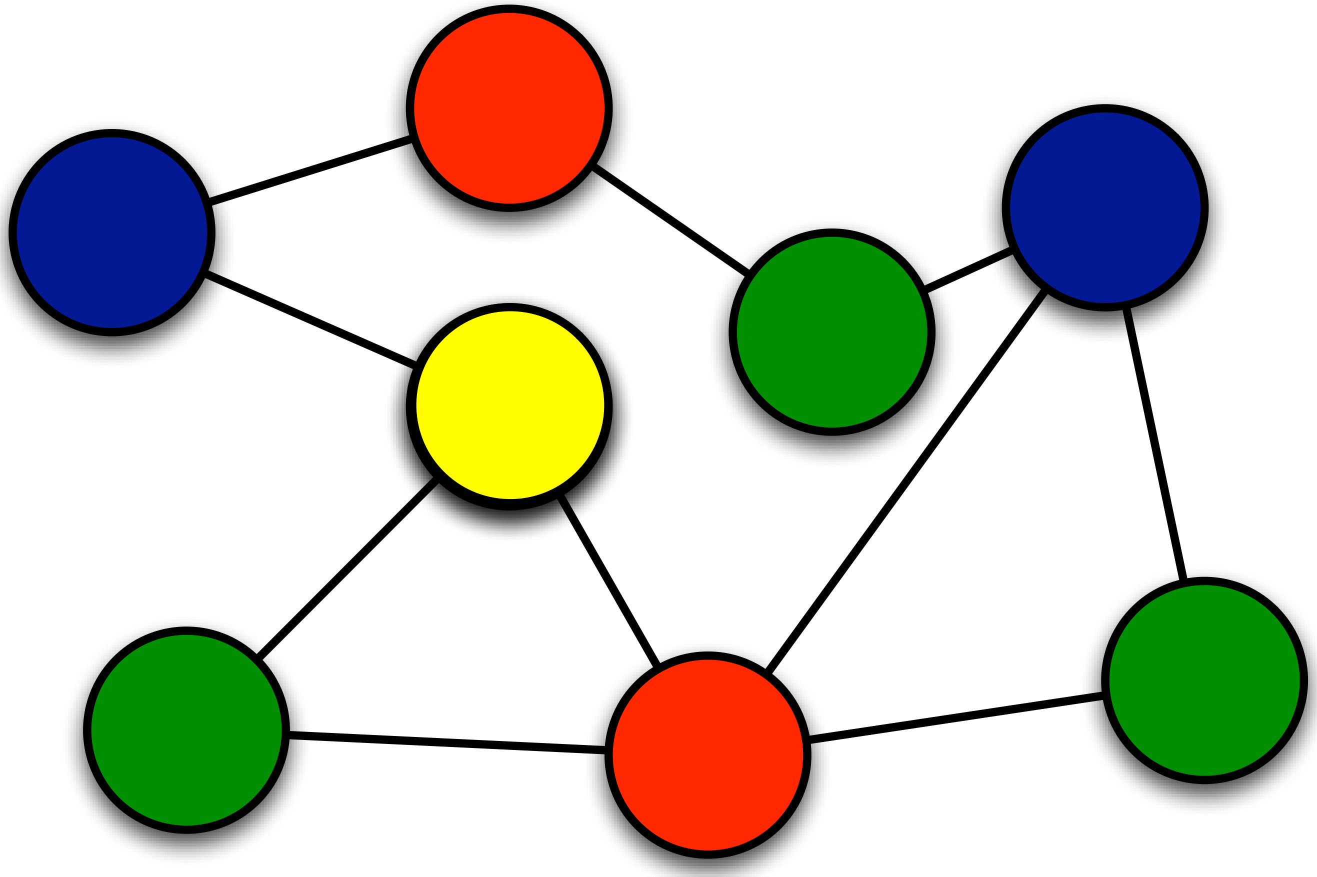

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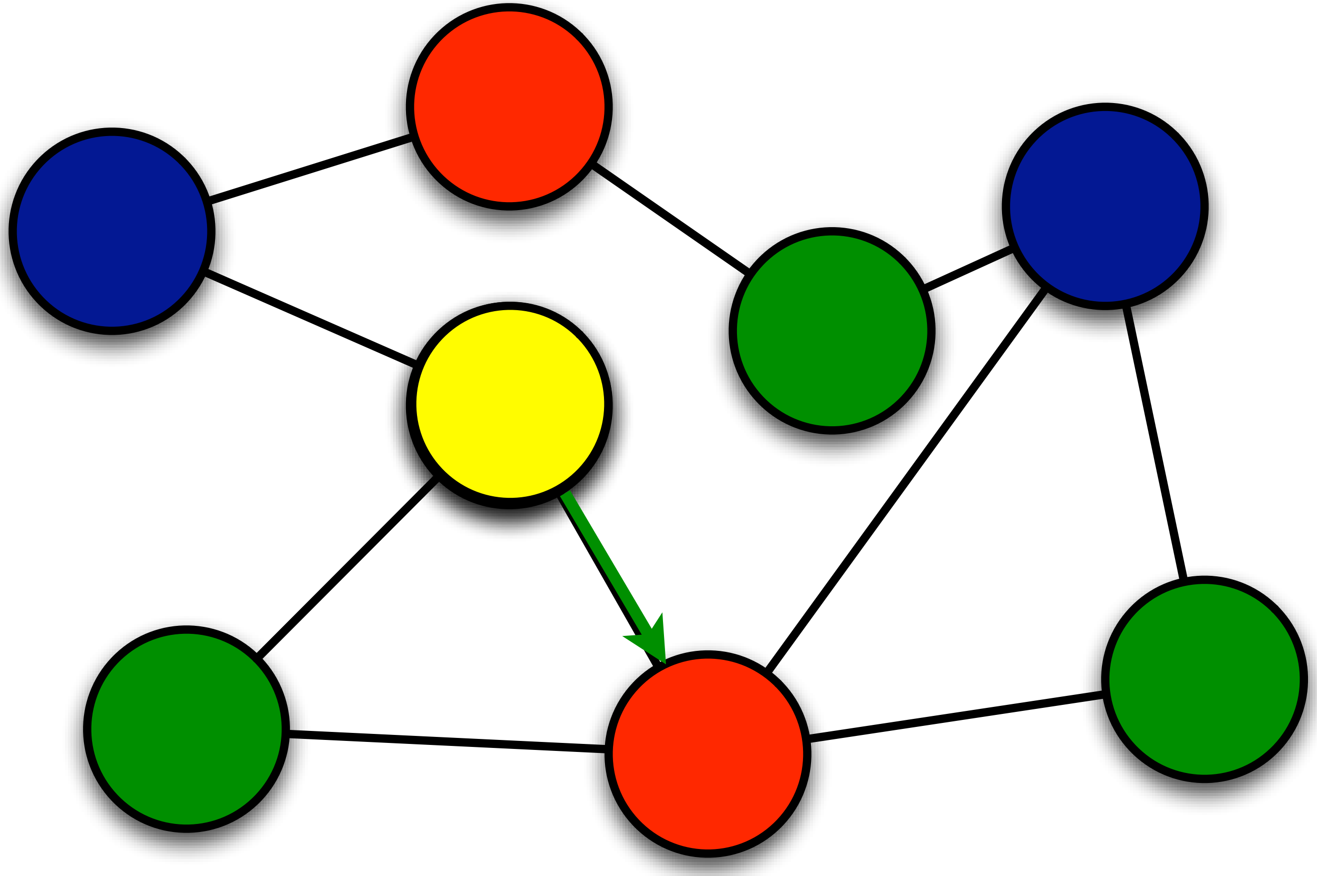

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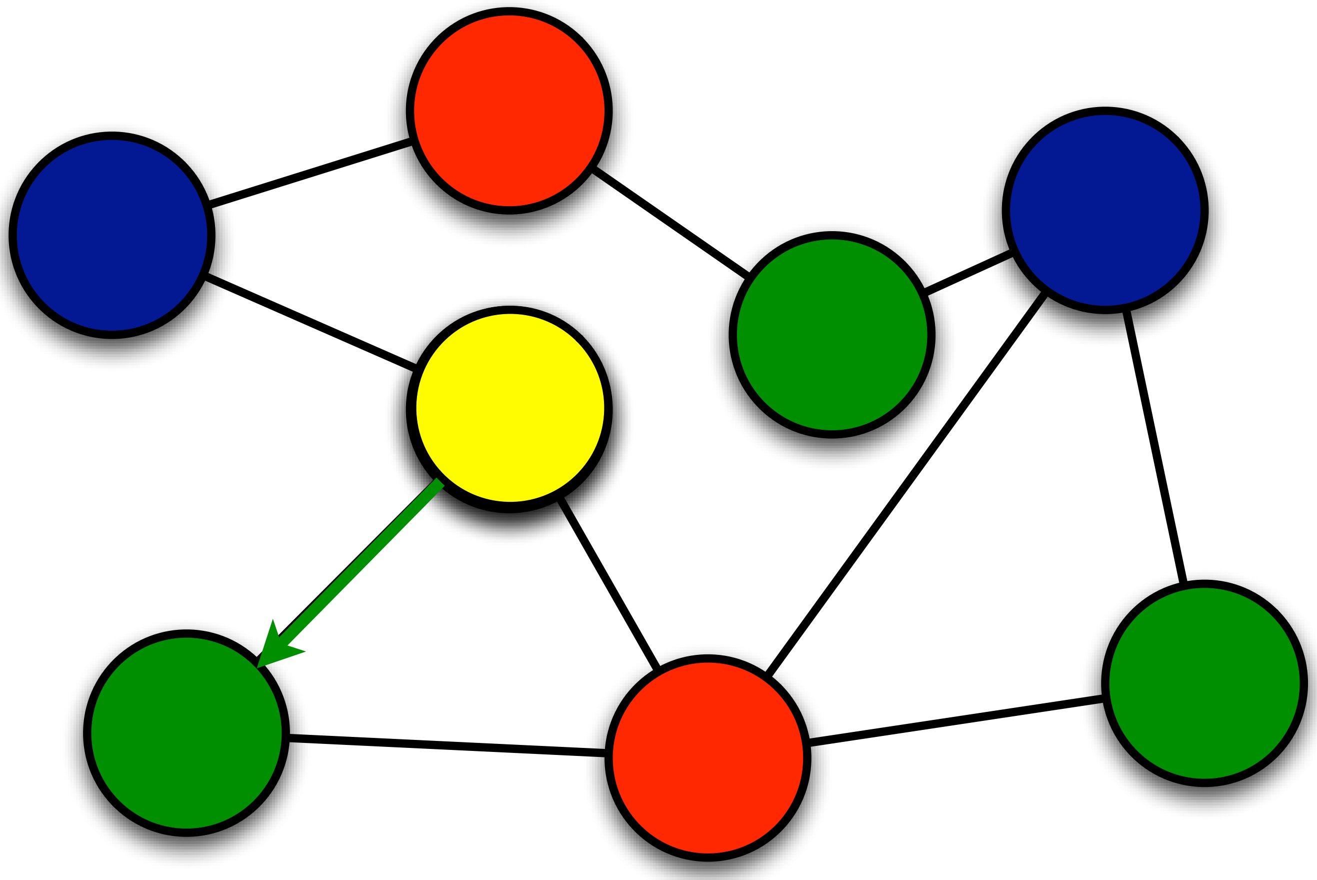

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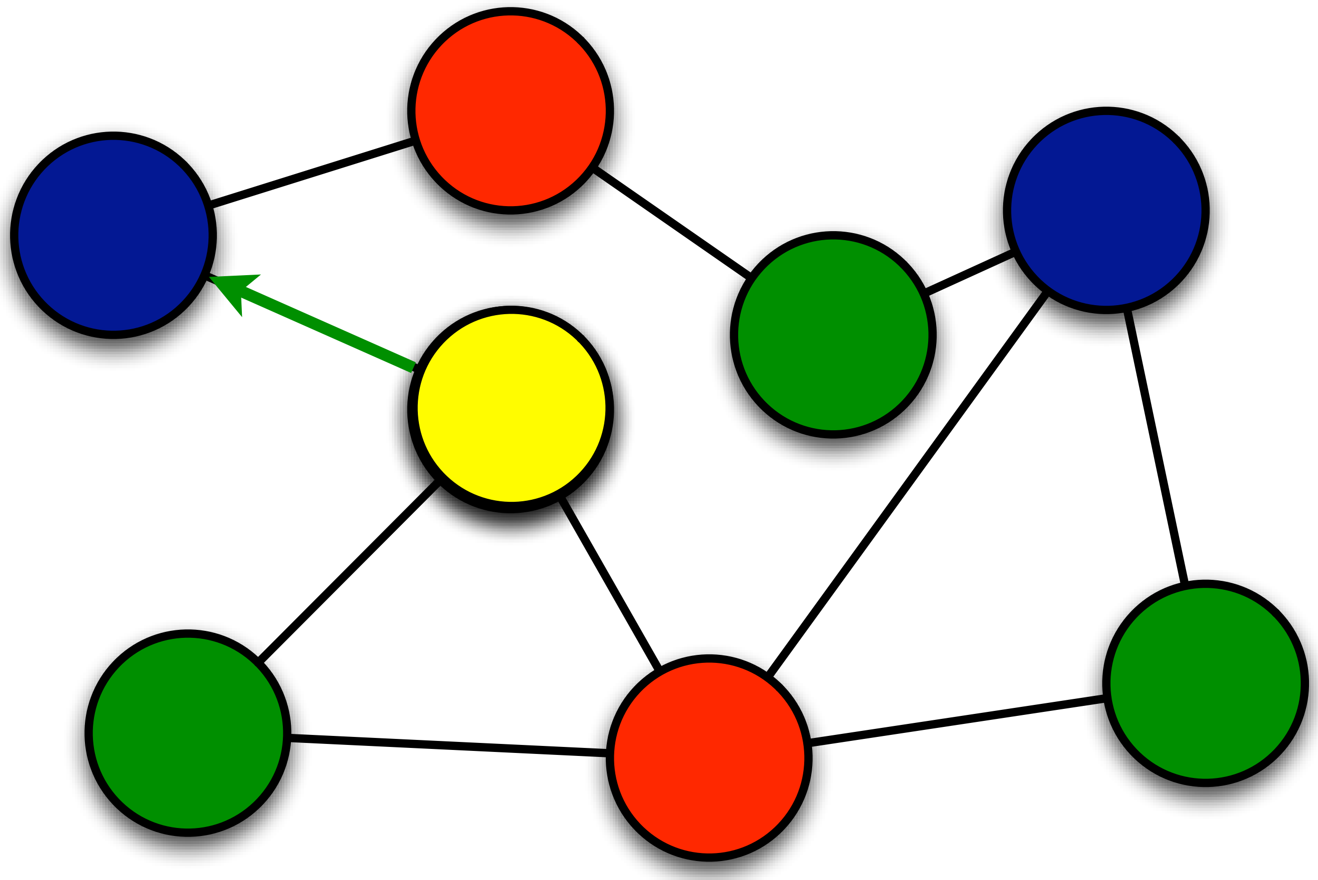
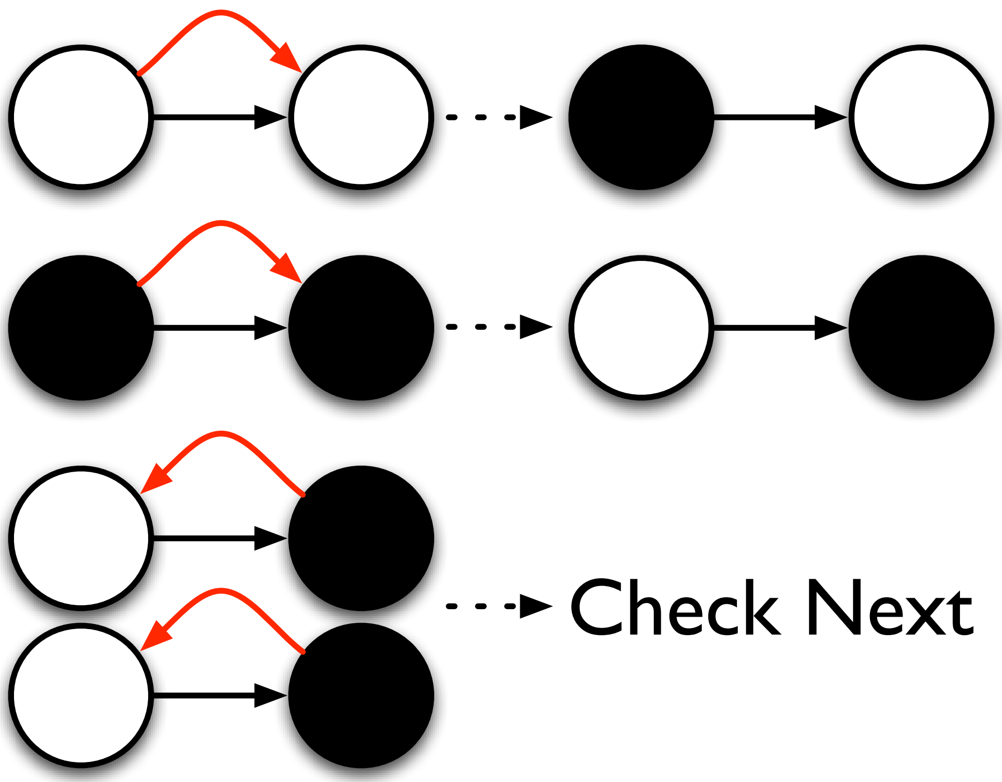


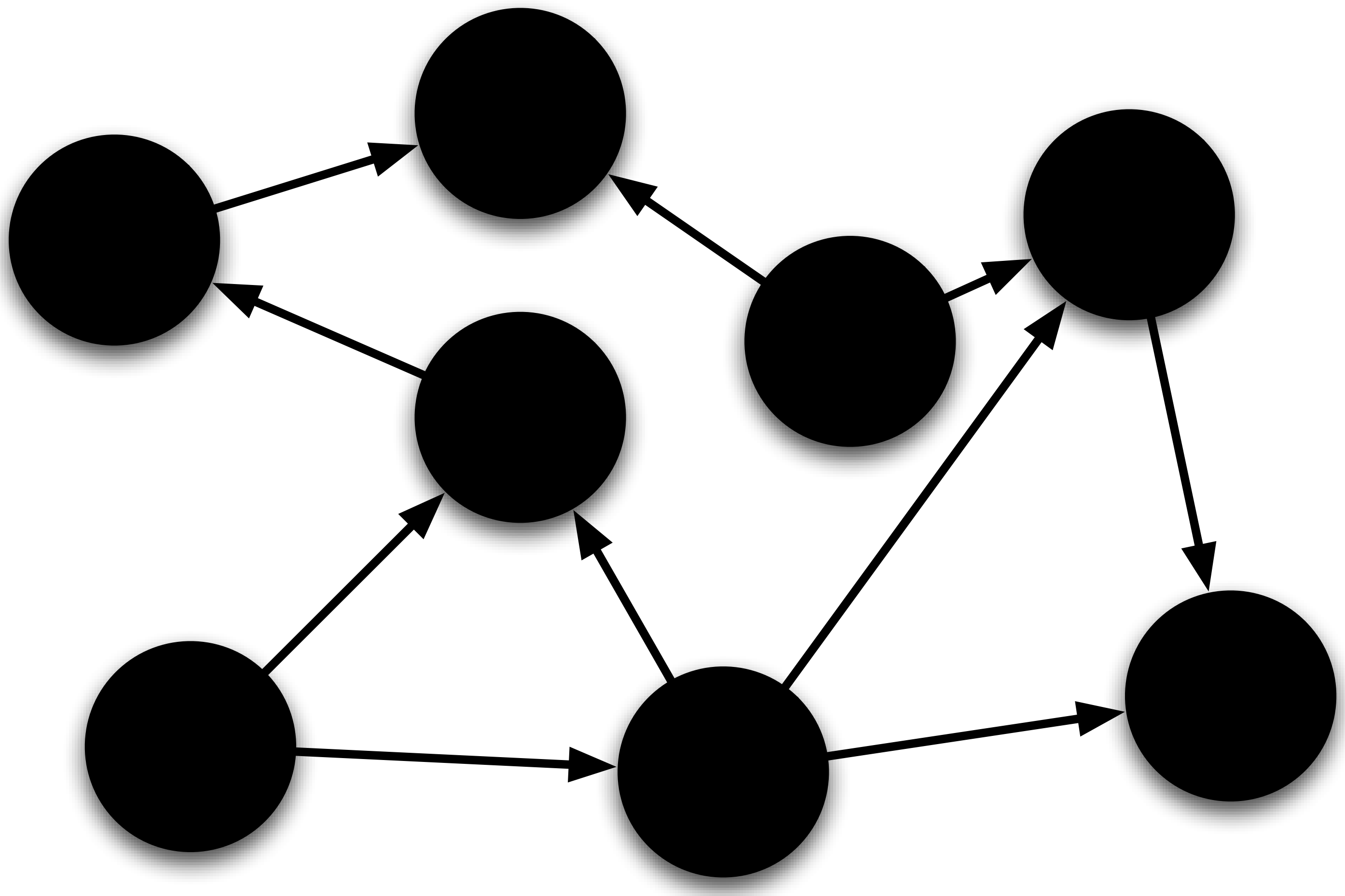
Communication Stability

- **k-stable**
- **eventual k-stable**
- **eventual (x,k)-stable**
  - In every *execution*, at least *x* nodes *eventually* communicate with at most k *different* neighbors

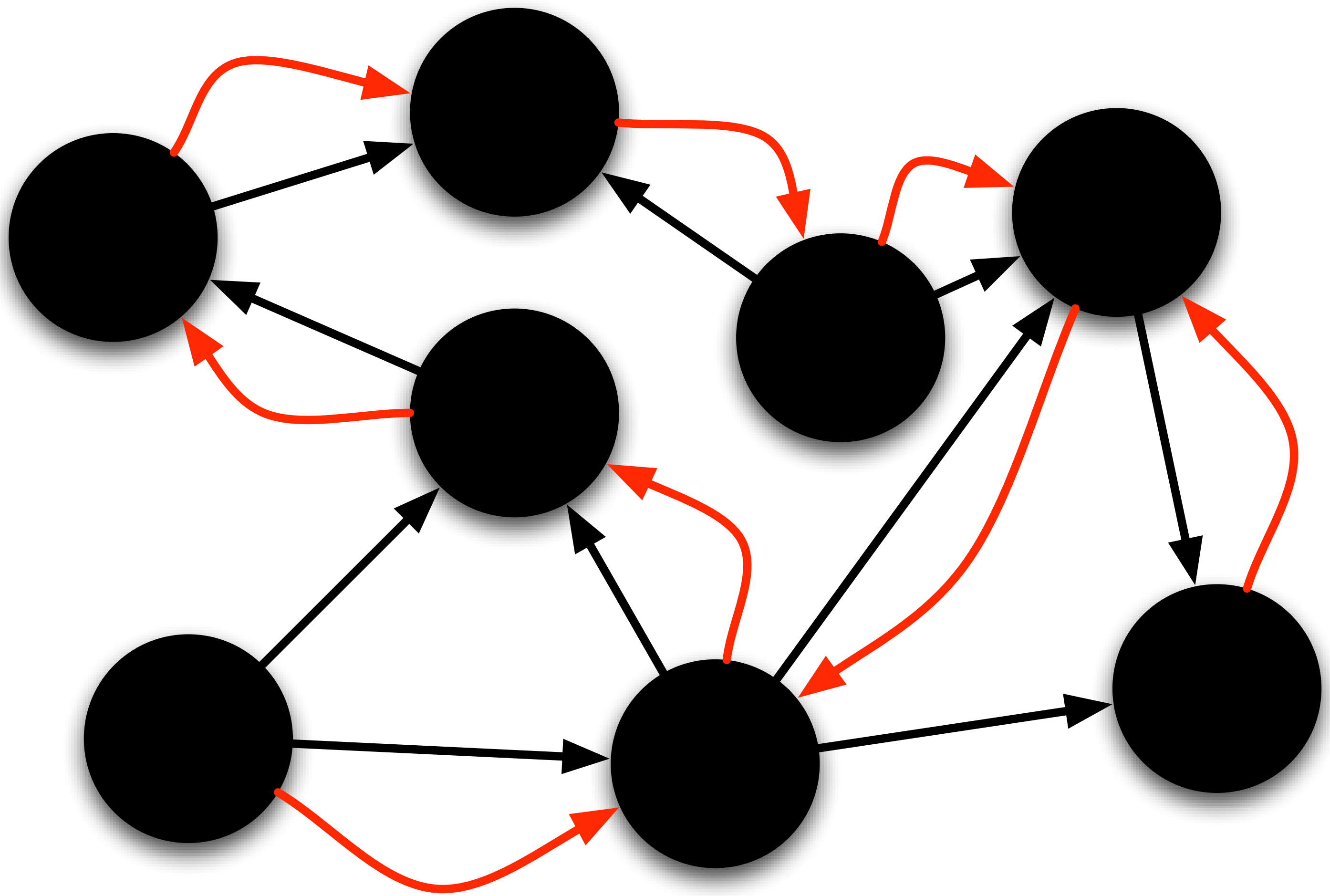
Maximal Independent Set (MIS)



Maximal Independent Set (MIS)



Maximal Independent Set (MIS)



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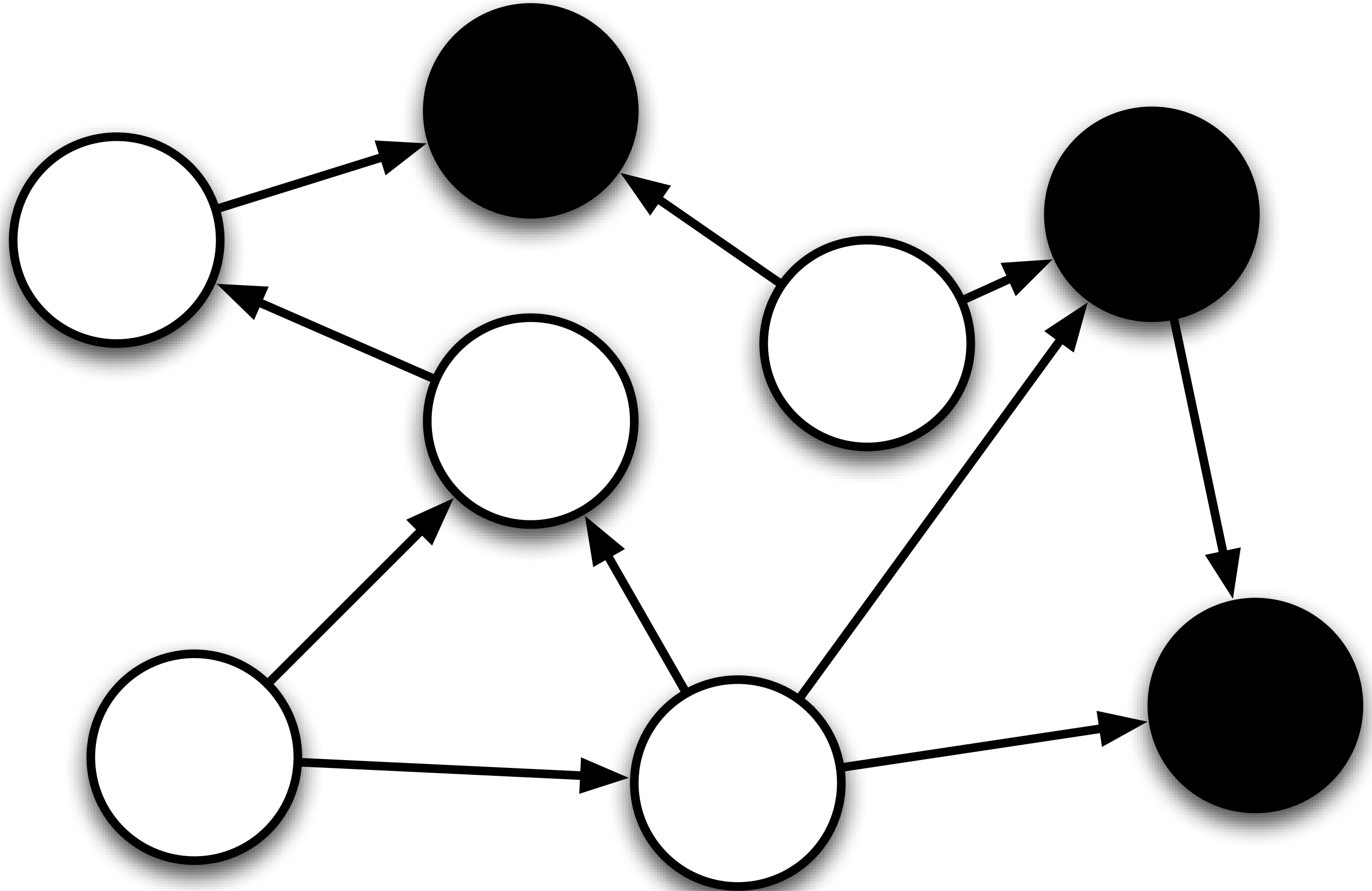

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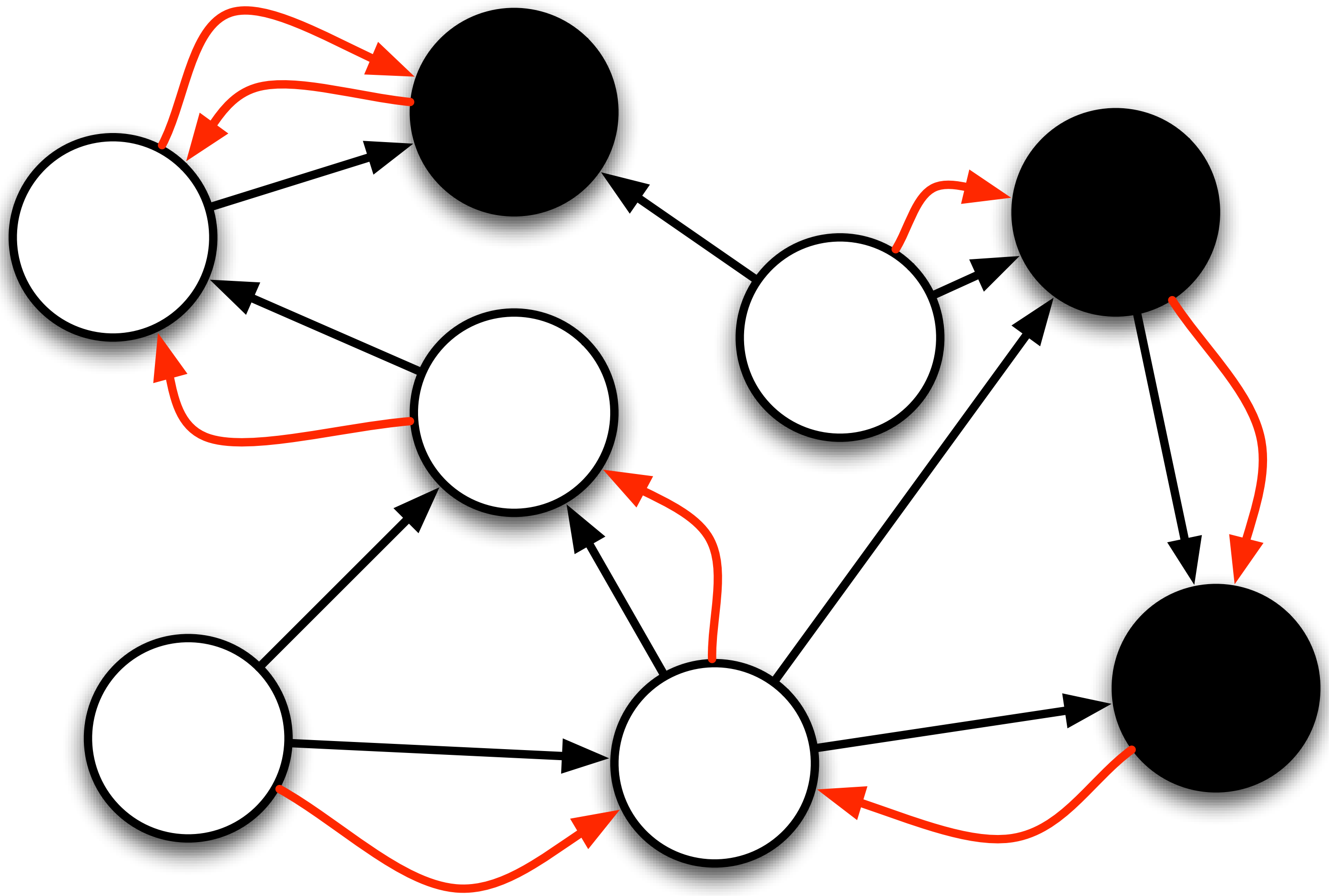

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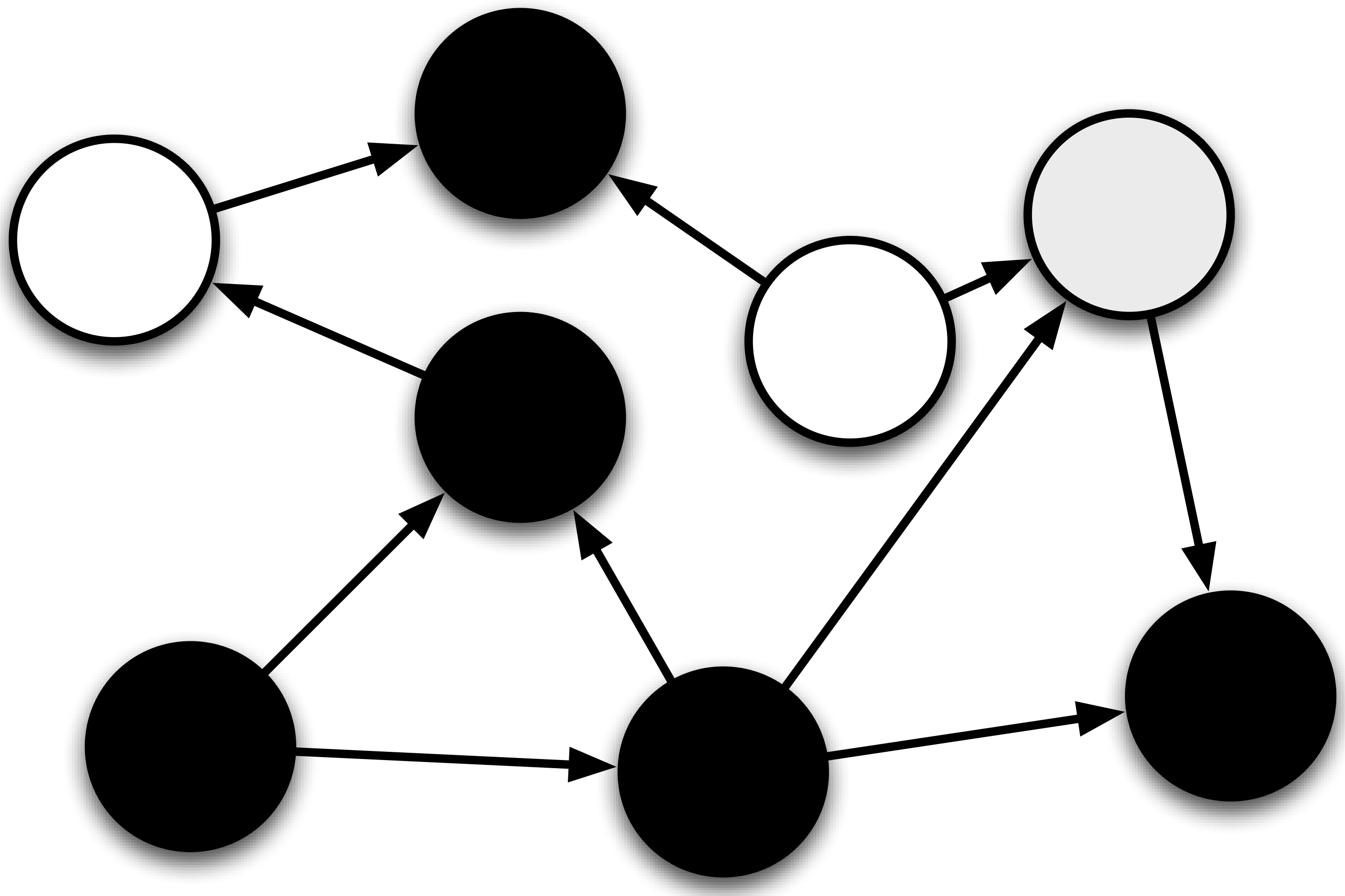

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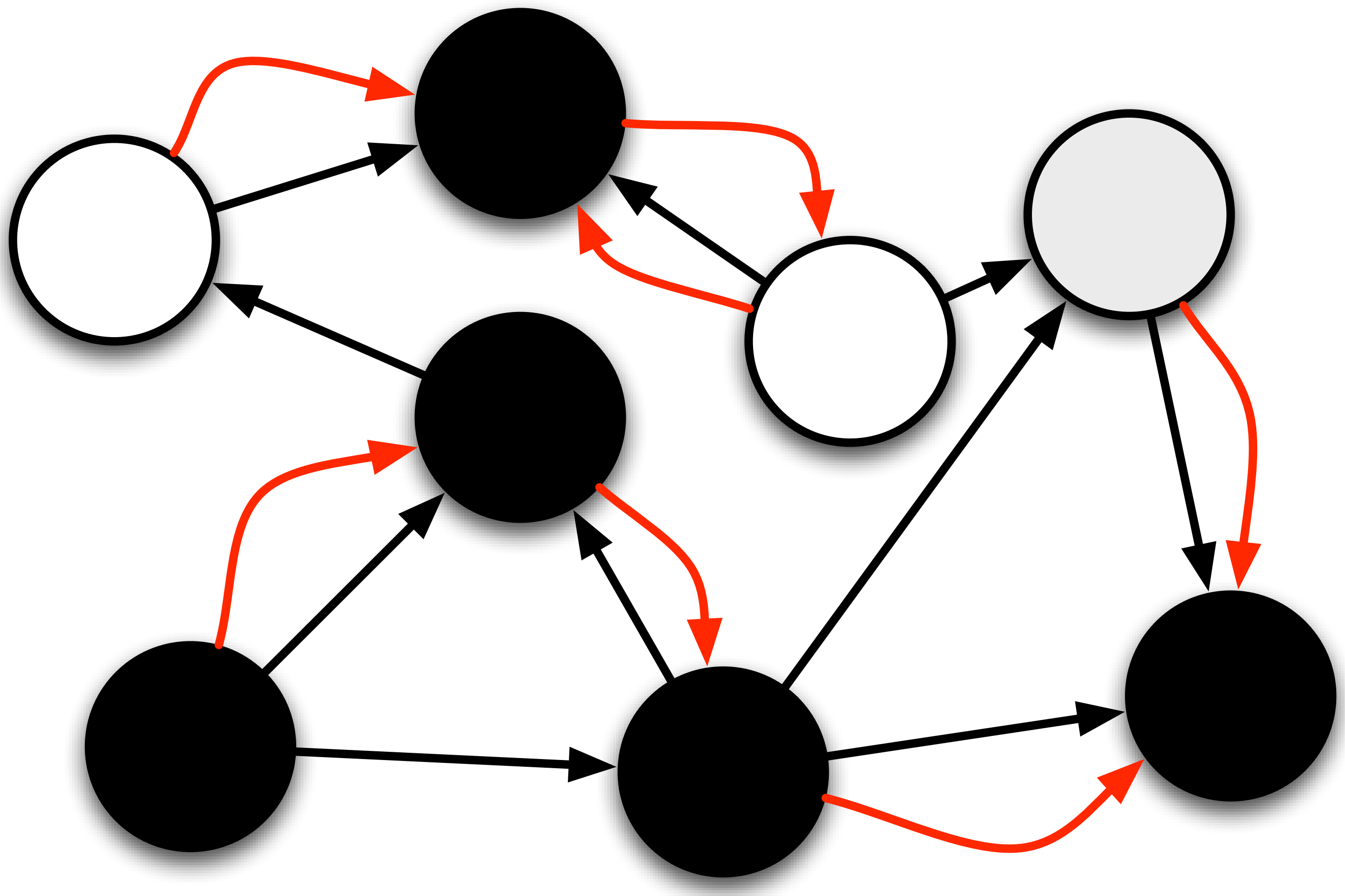

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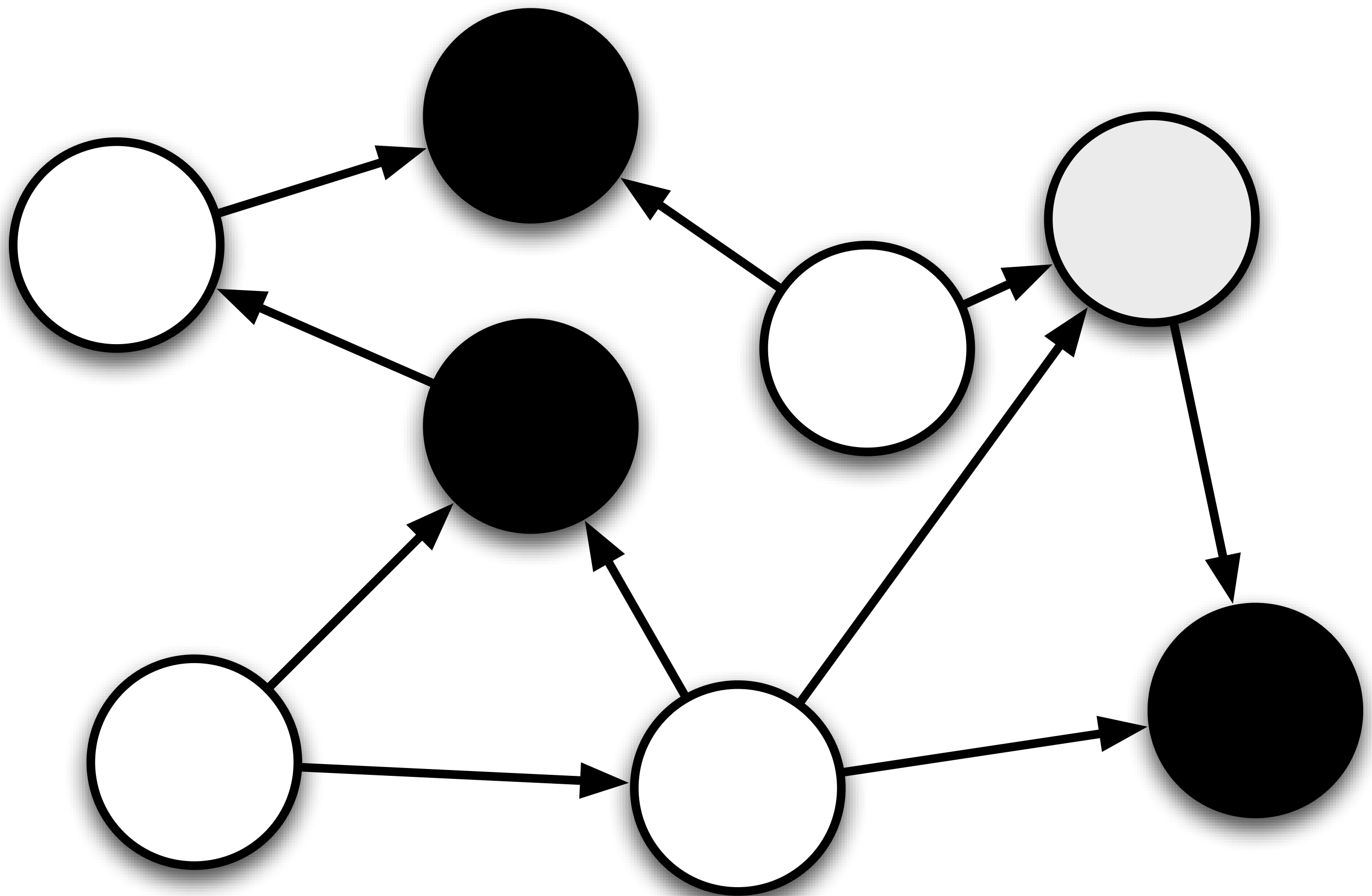
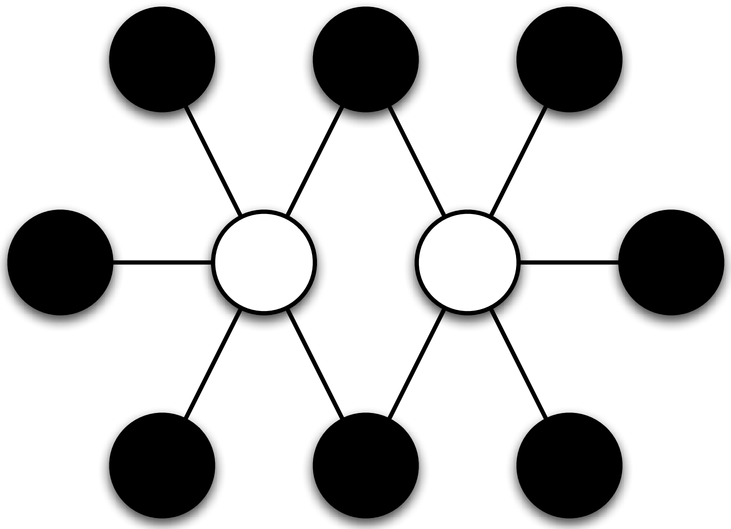


Maximal Independent Set (MIS)

- **Theorem**
  - MIS protocol is 1-efficient and eventual $(\lfloor \frac{\mathcal{L}+1}{2} \rfloor, 1)$ stable

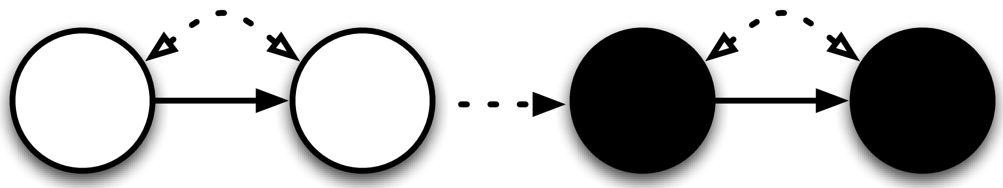


Maximal Matching

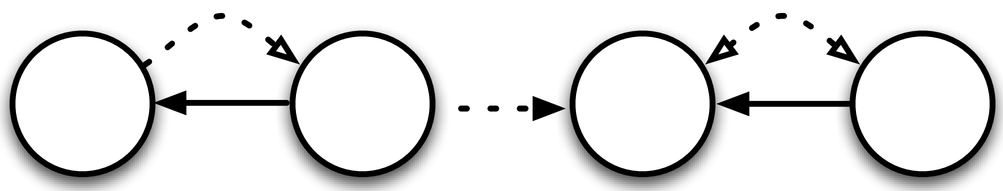
- *Derived from*
  - *Manne, Mjede, Pilard, Tixeuil,* A new self-stabilizing Maximal Matching Algorithm, Sirocco 2007
- *Main difference*: **Stay Focused**
  - Interact with a single neighbor at a time

Maximal Matching

- Don't lie about your marital status

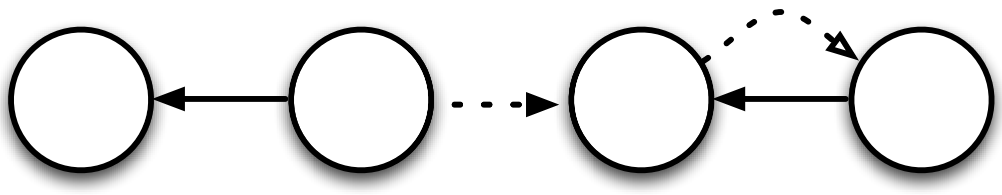


- Don't be picky

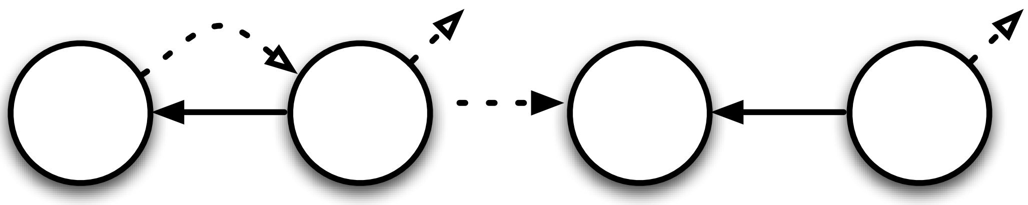


Maximal Matching

- Expect the best

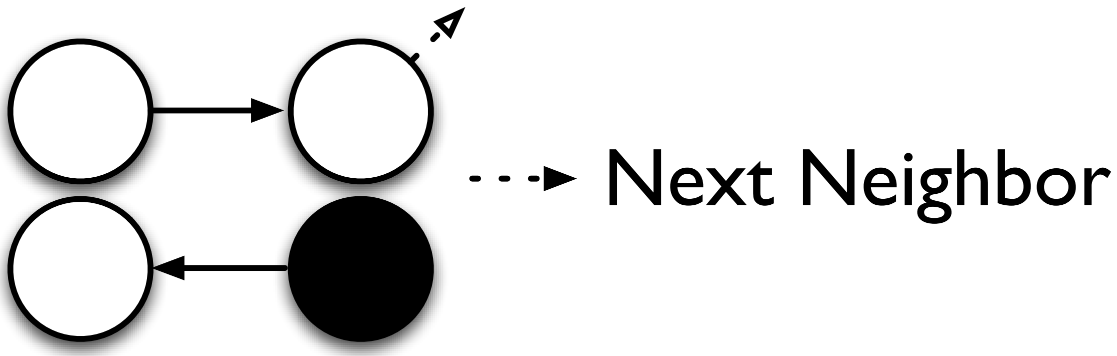


- Accept the worst

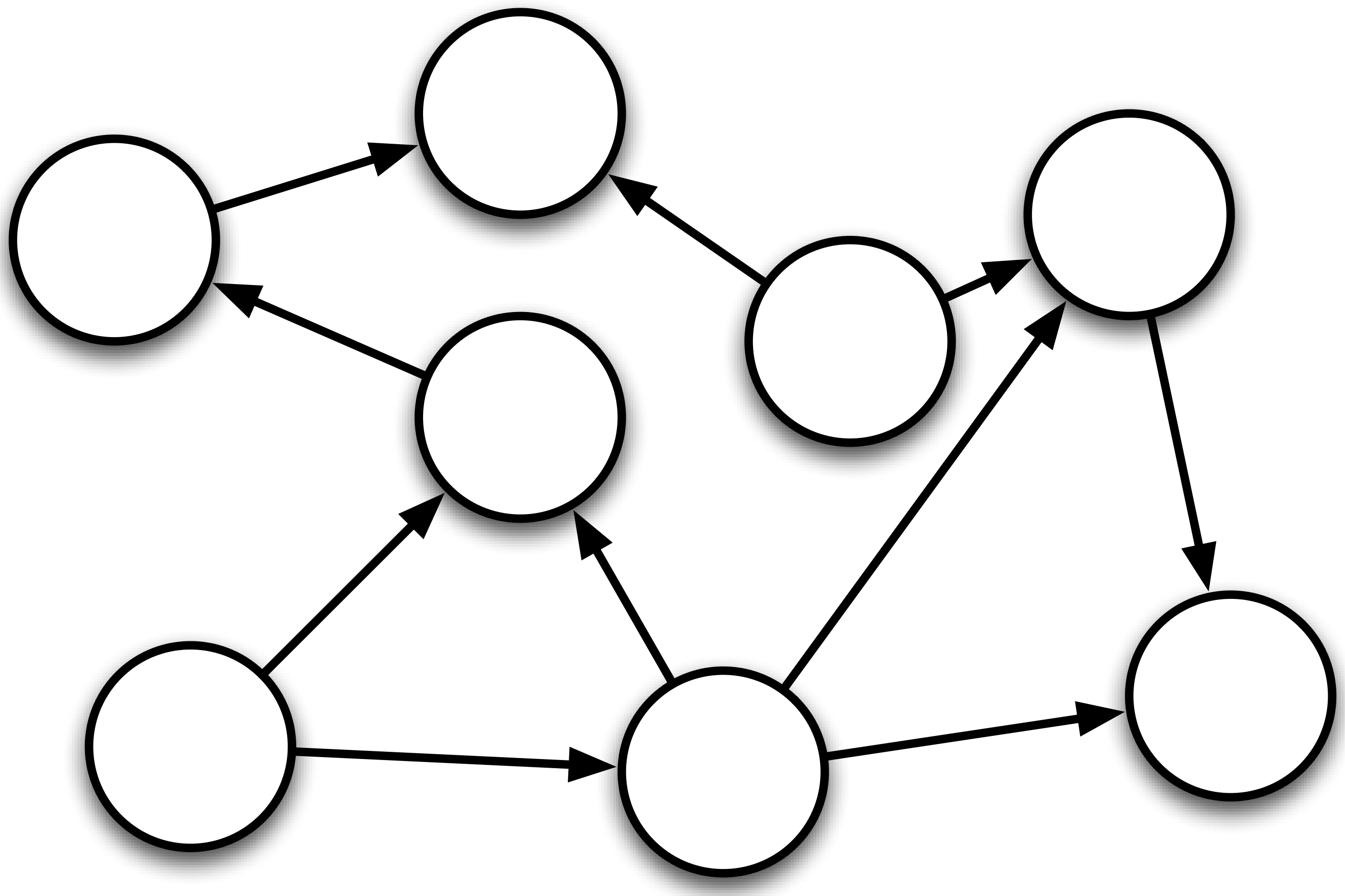


Maximal Matching

- Keep looking



Maximal Matching



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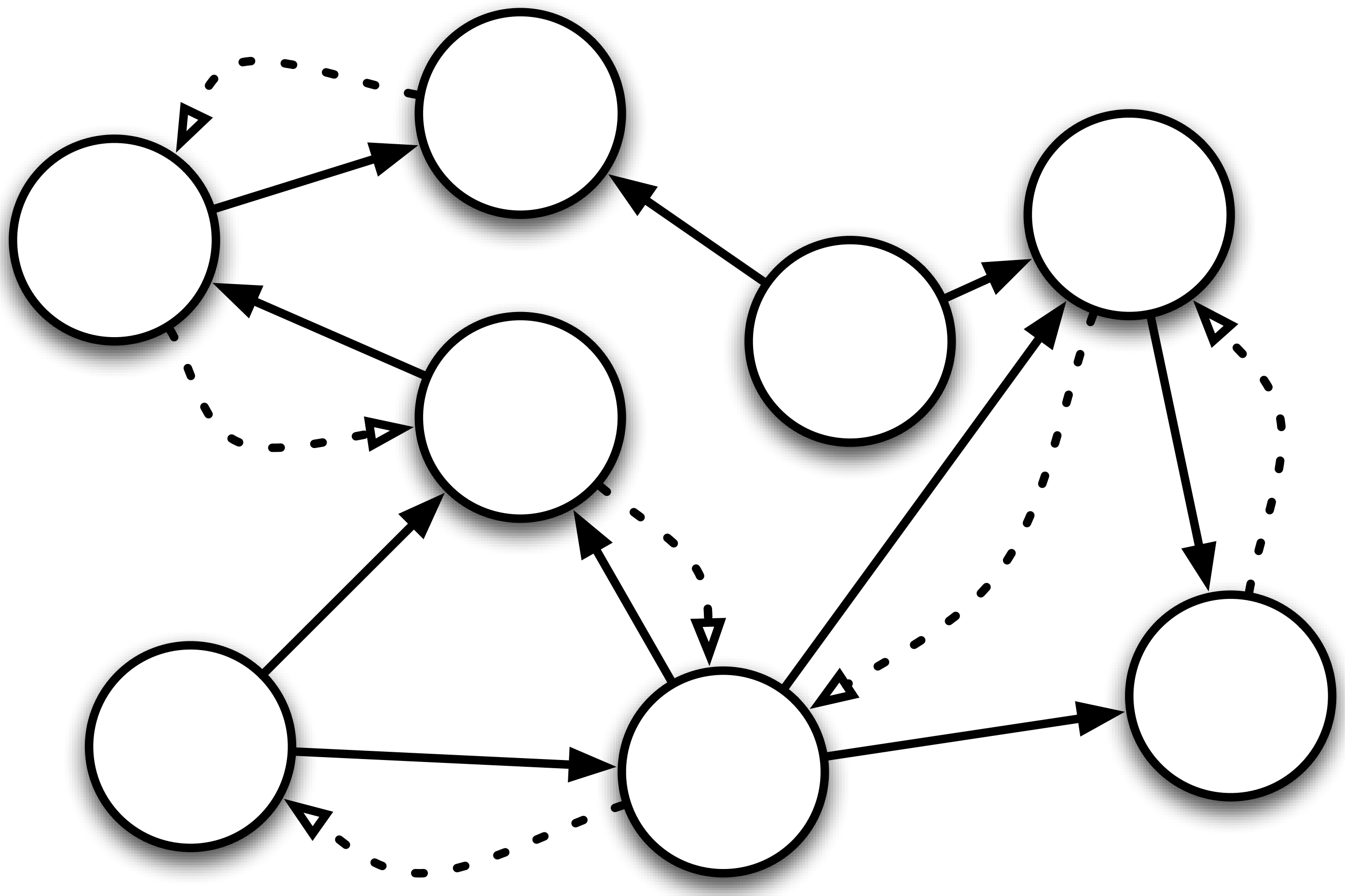

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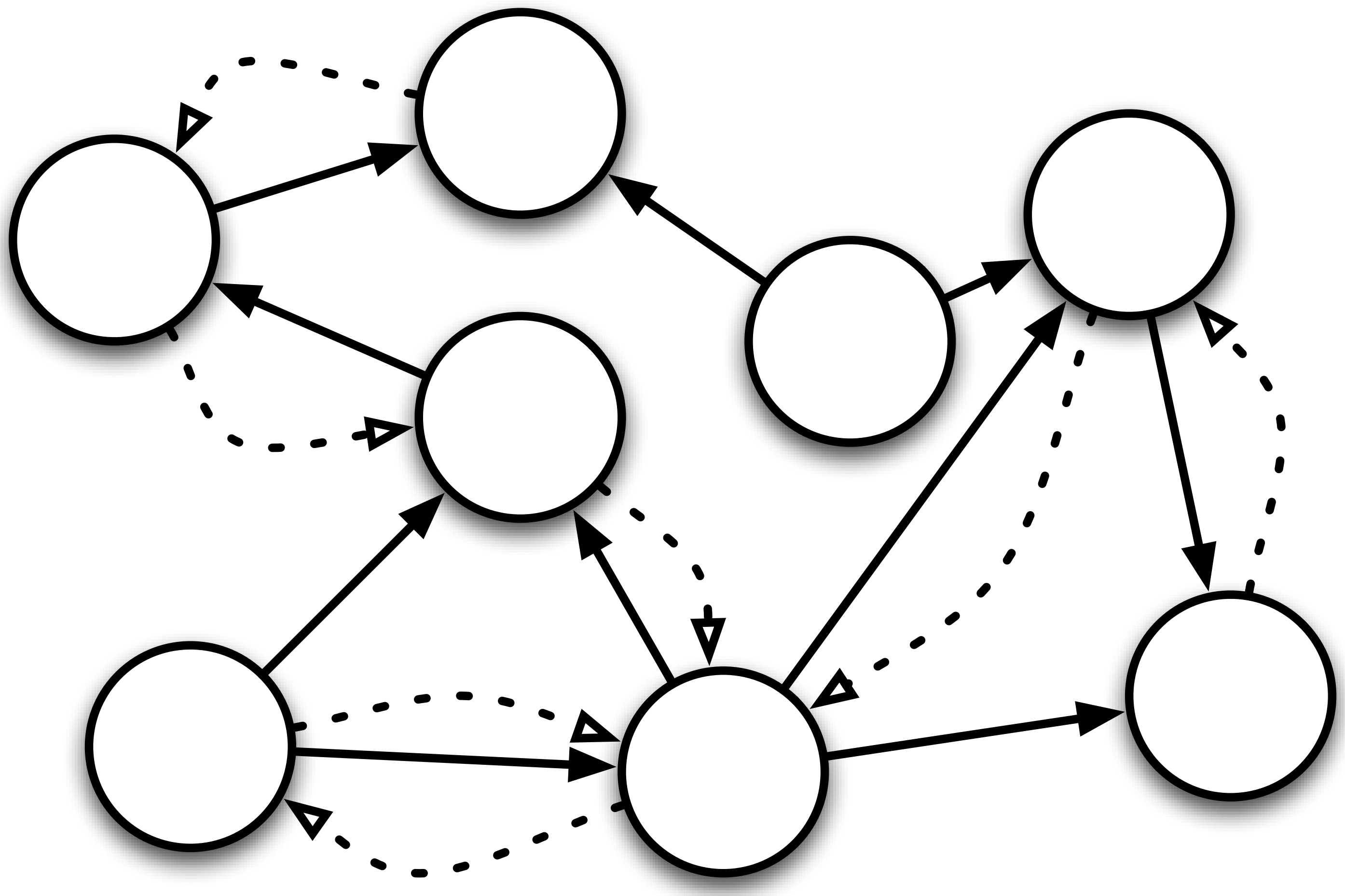

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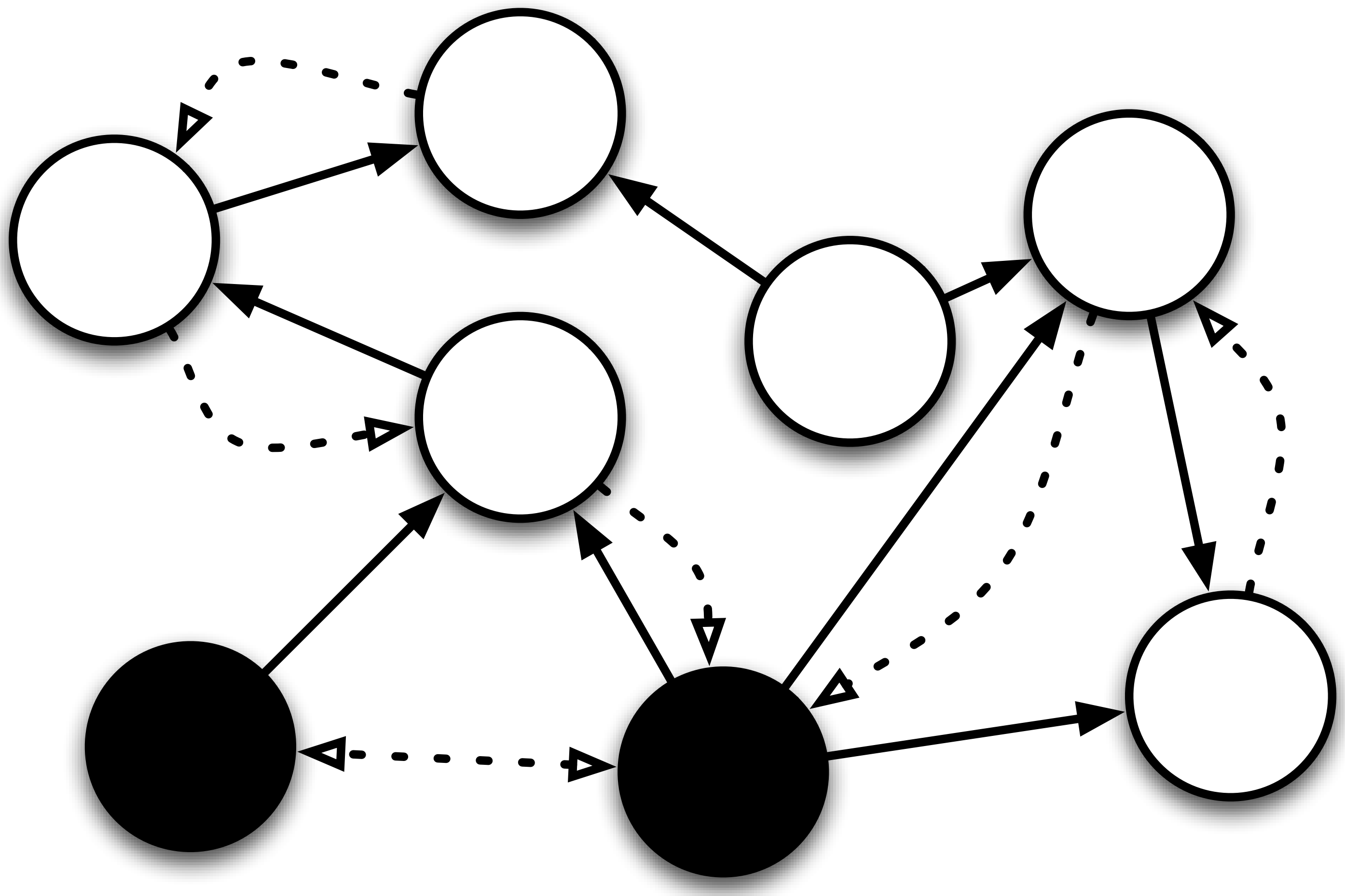

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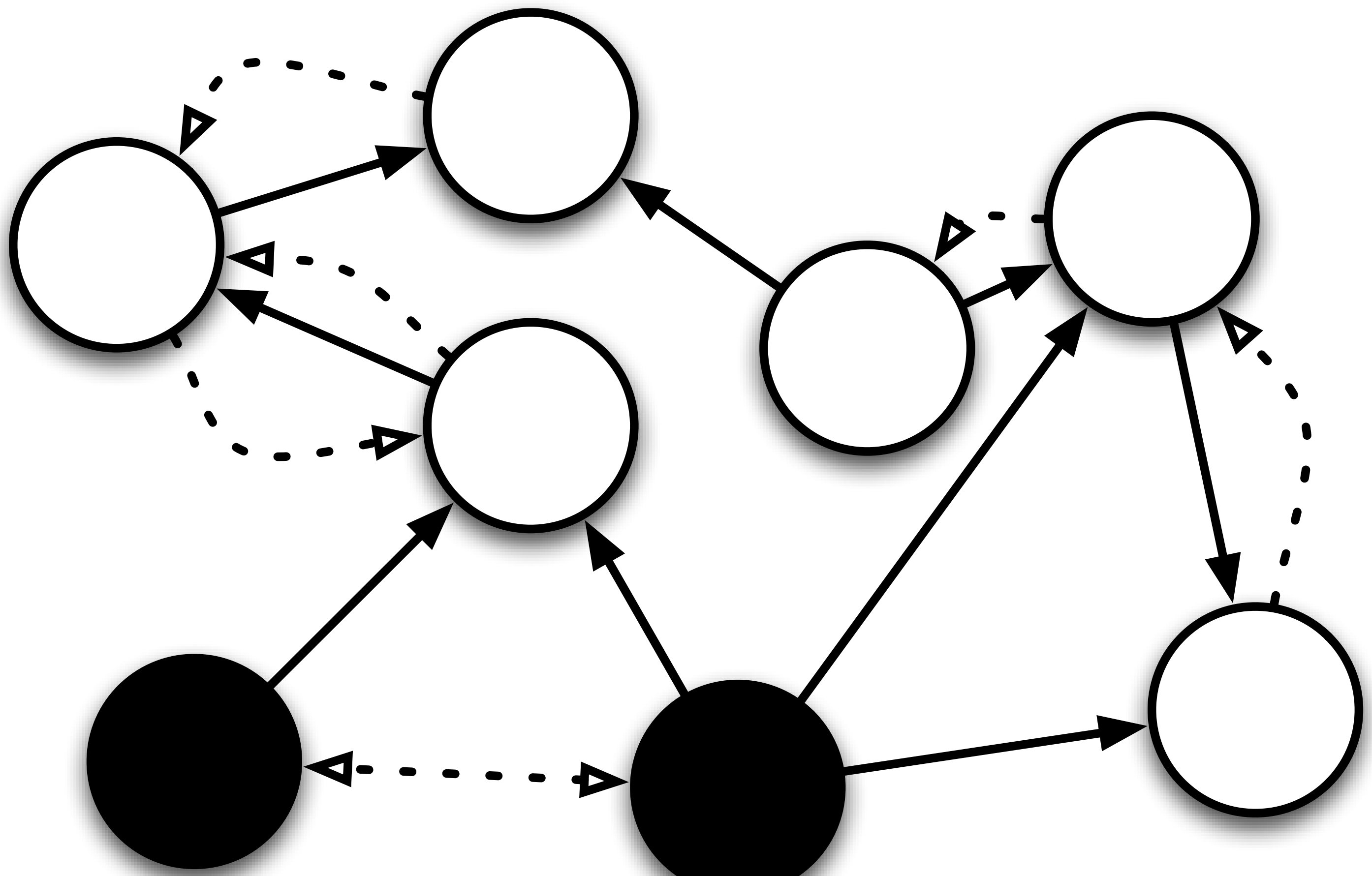

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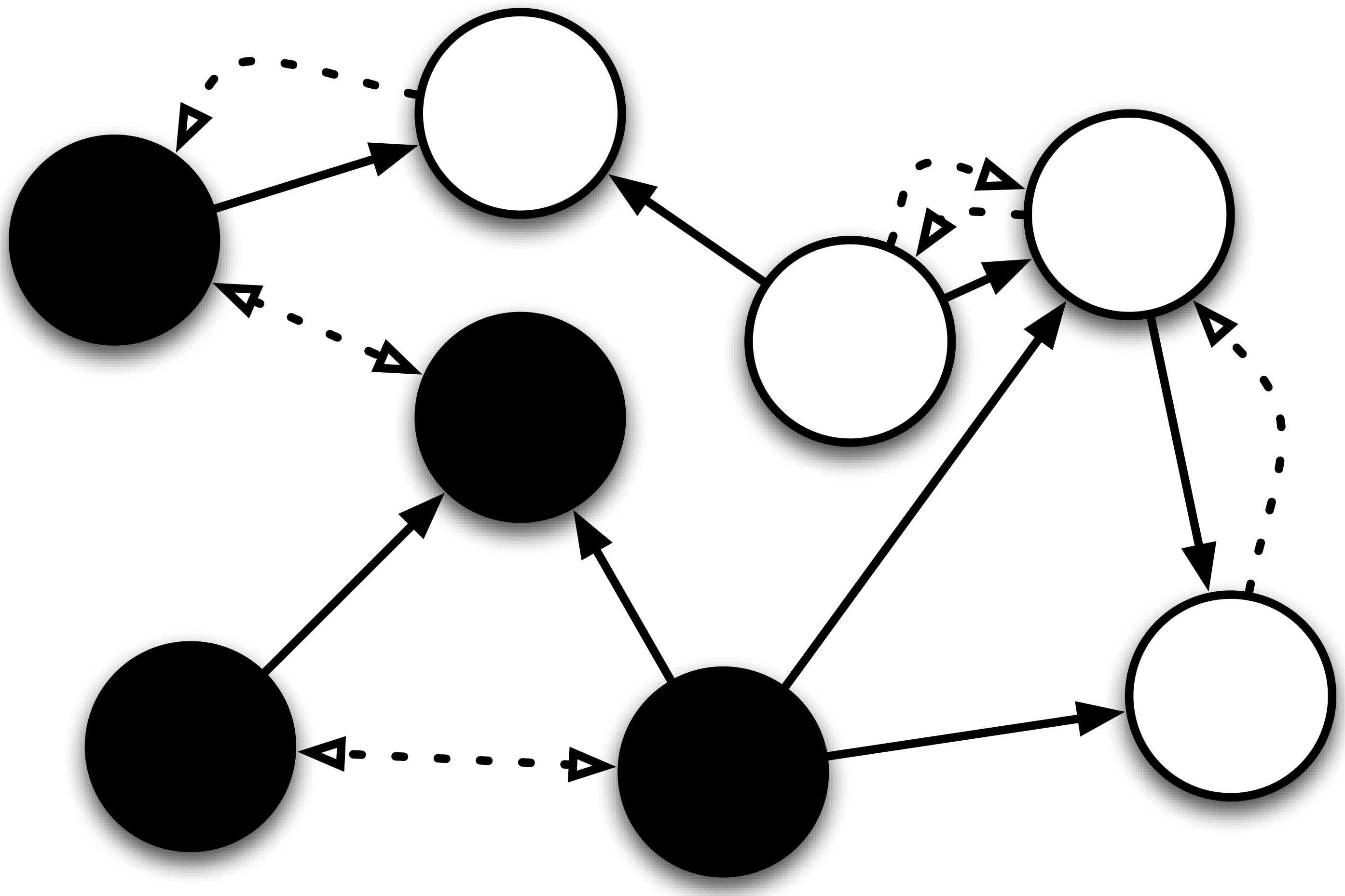

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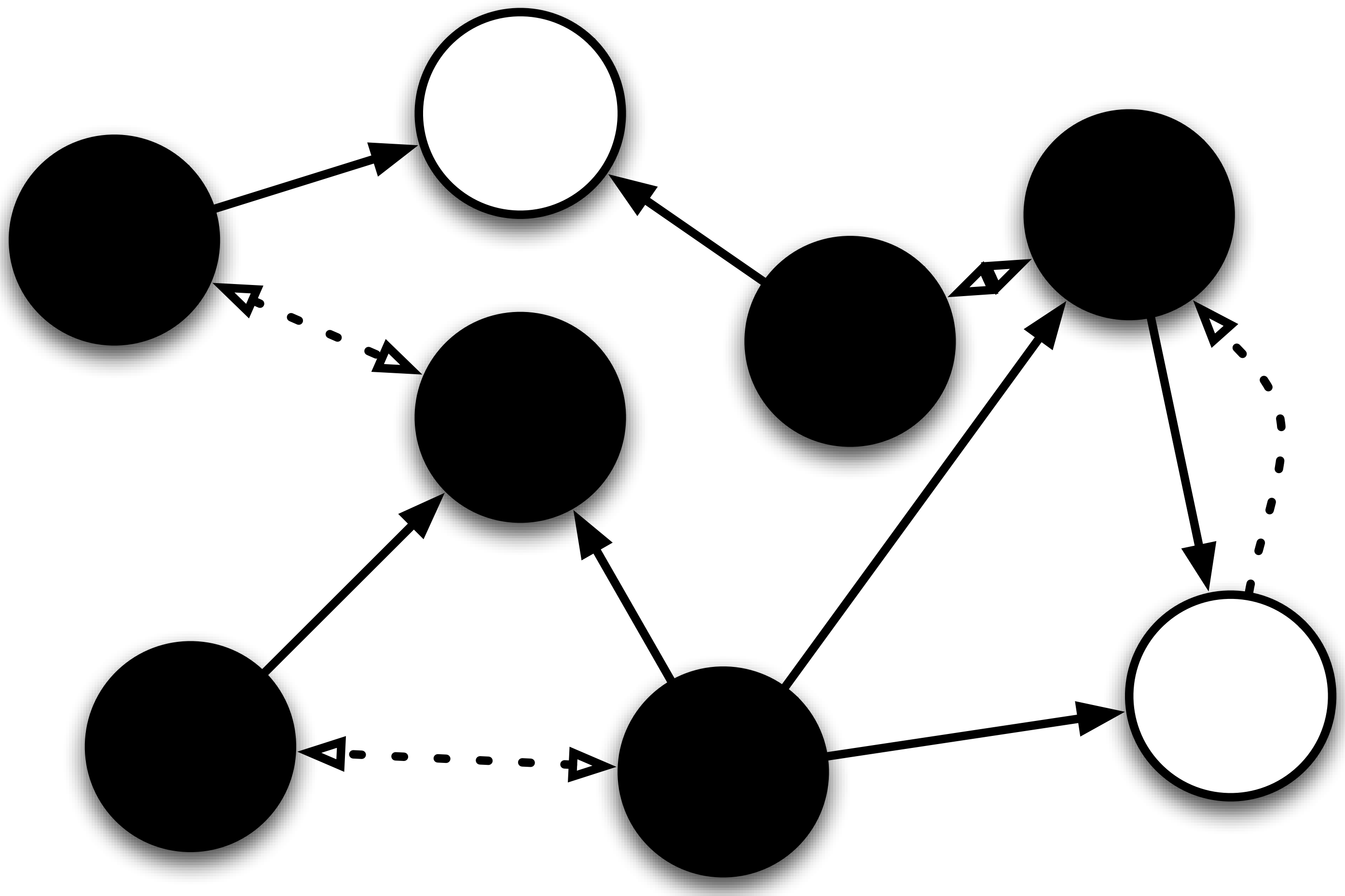

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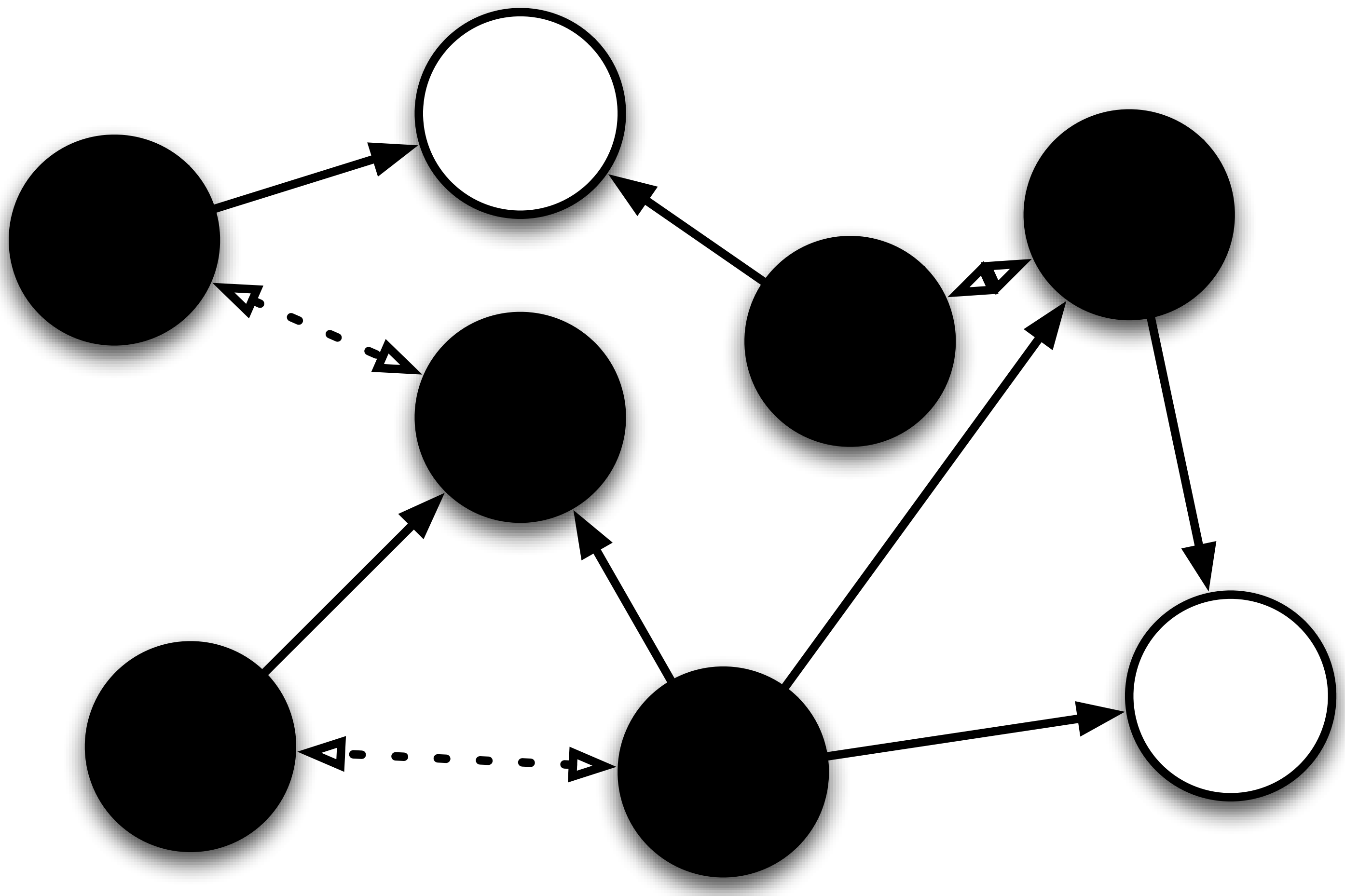
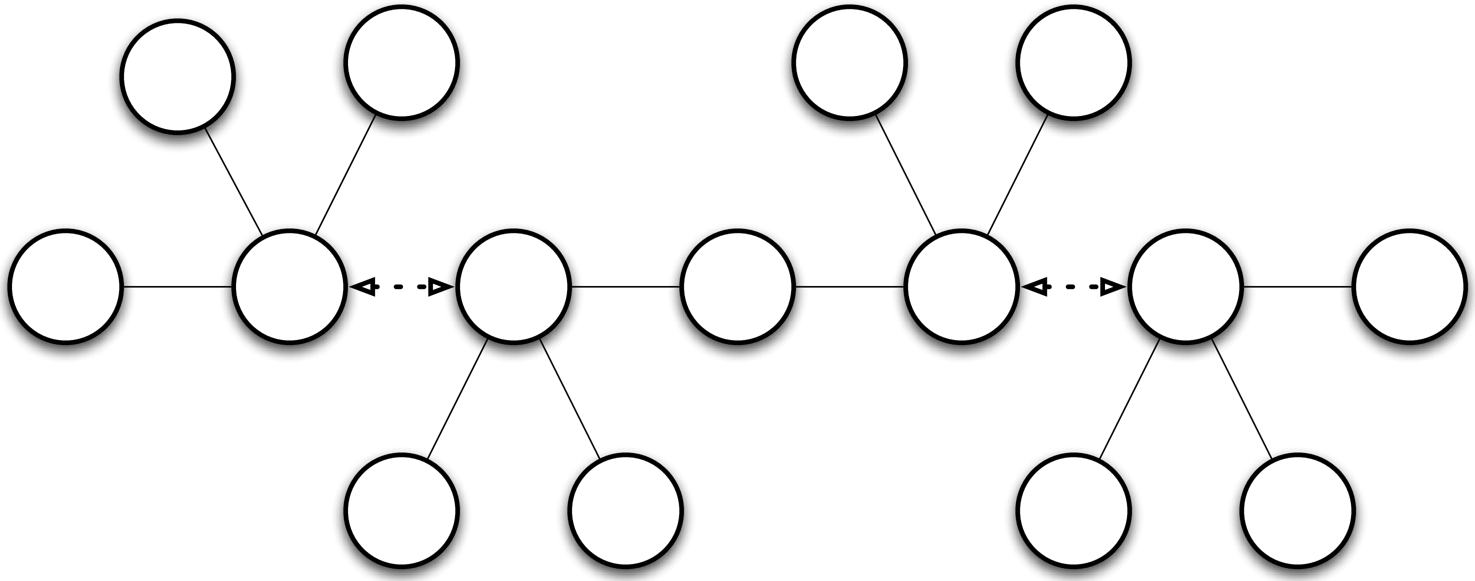


Maximal matching

- **Theorem**
  - The Maximal Matching protocol is eventual $(\lceil \frac{2m}{2\Delta - 1} \rceil, 1)$-stable



Conclusion

- *New measure* for communication efficiency in self-stabilizing protocols
- Hints at *efficient implementation* in real networks
- *Orthogonal* to "graph oriented" quality of the protocols

Perspectives

- Applicability to *non-silent* protocols
- Lower bounds on *x* for eventual *(x,k)*-stability
- Theoretical problem quality *vs.* practical efficiency