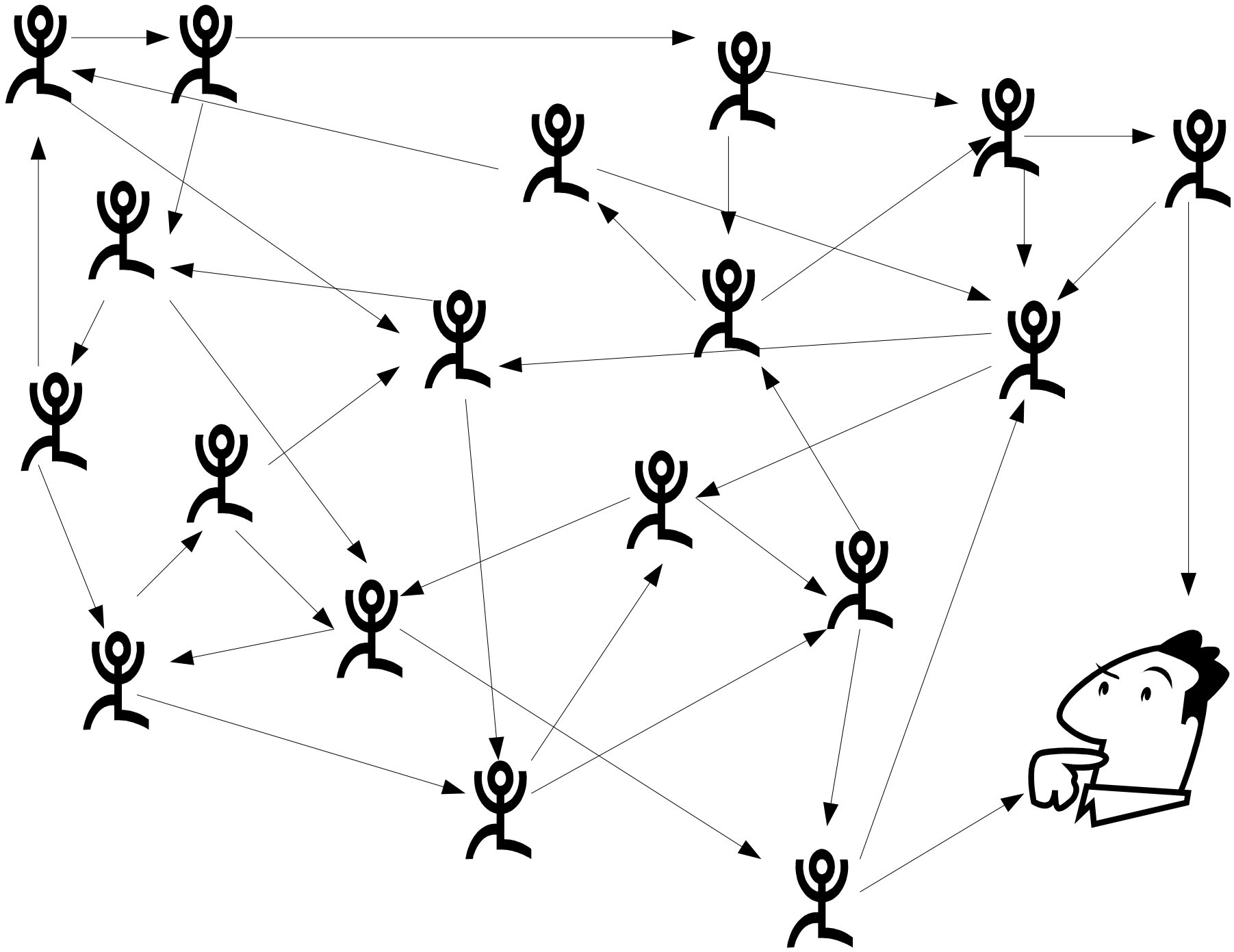


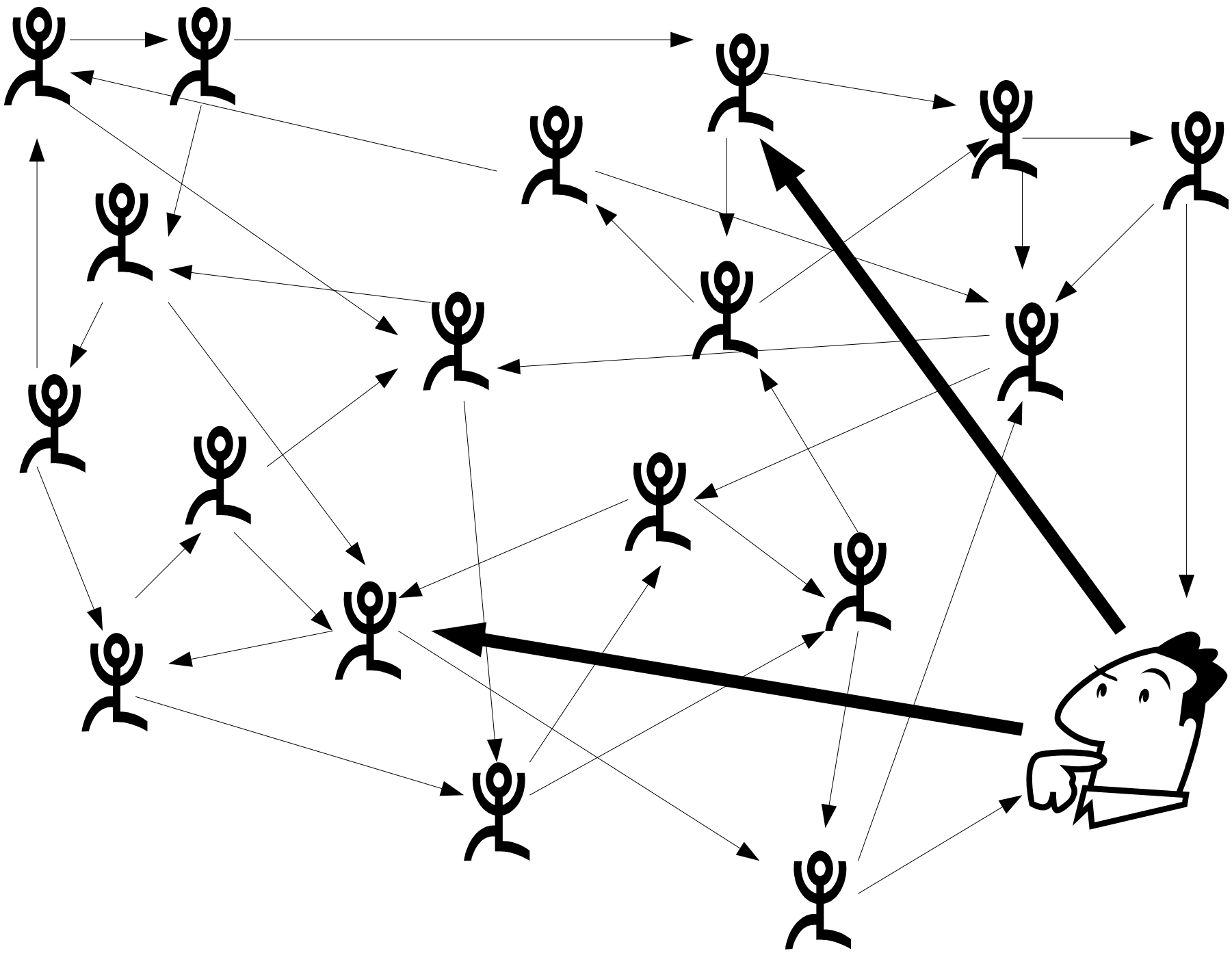
Bounded Budget Connection Games

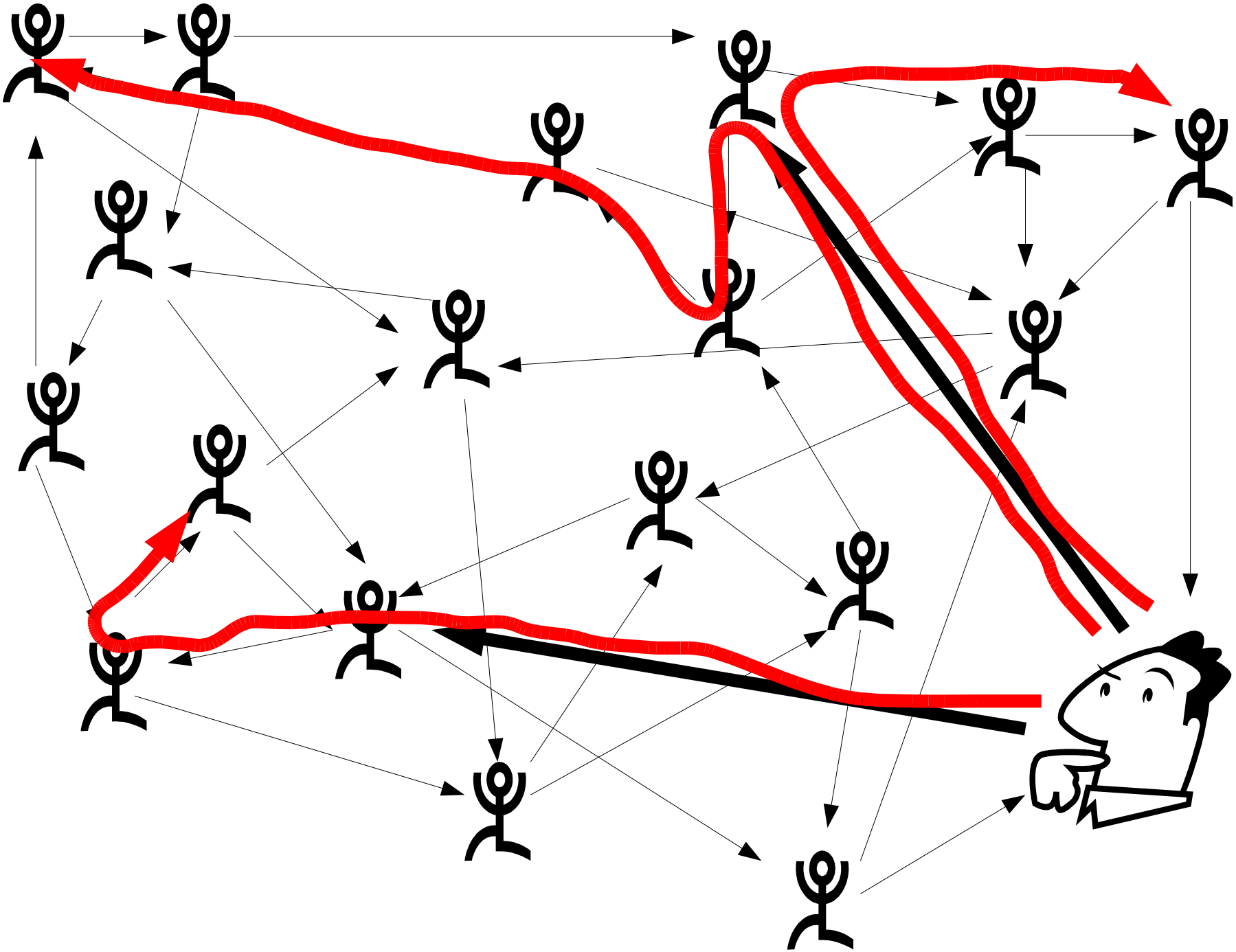
or how to make friends and
influence people, on a budget

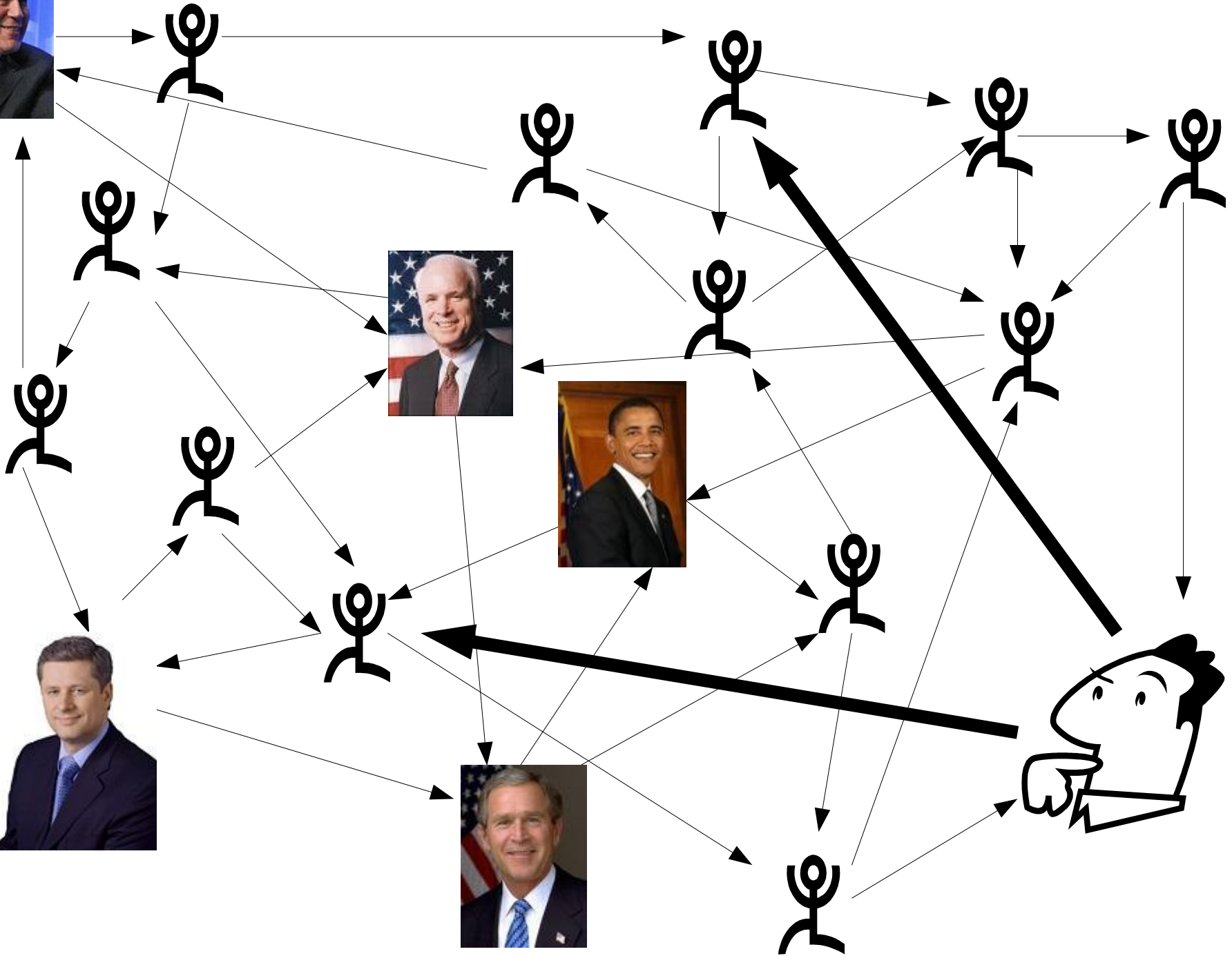
Laura Poplawski
Northeastern University

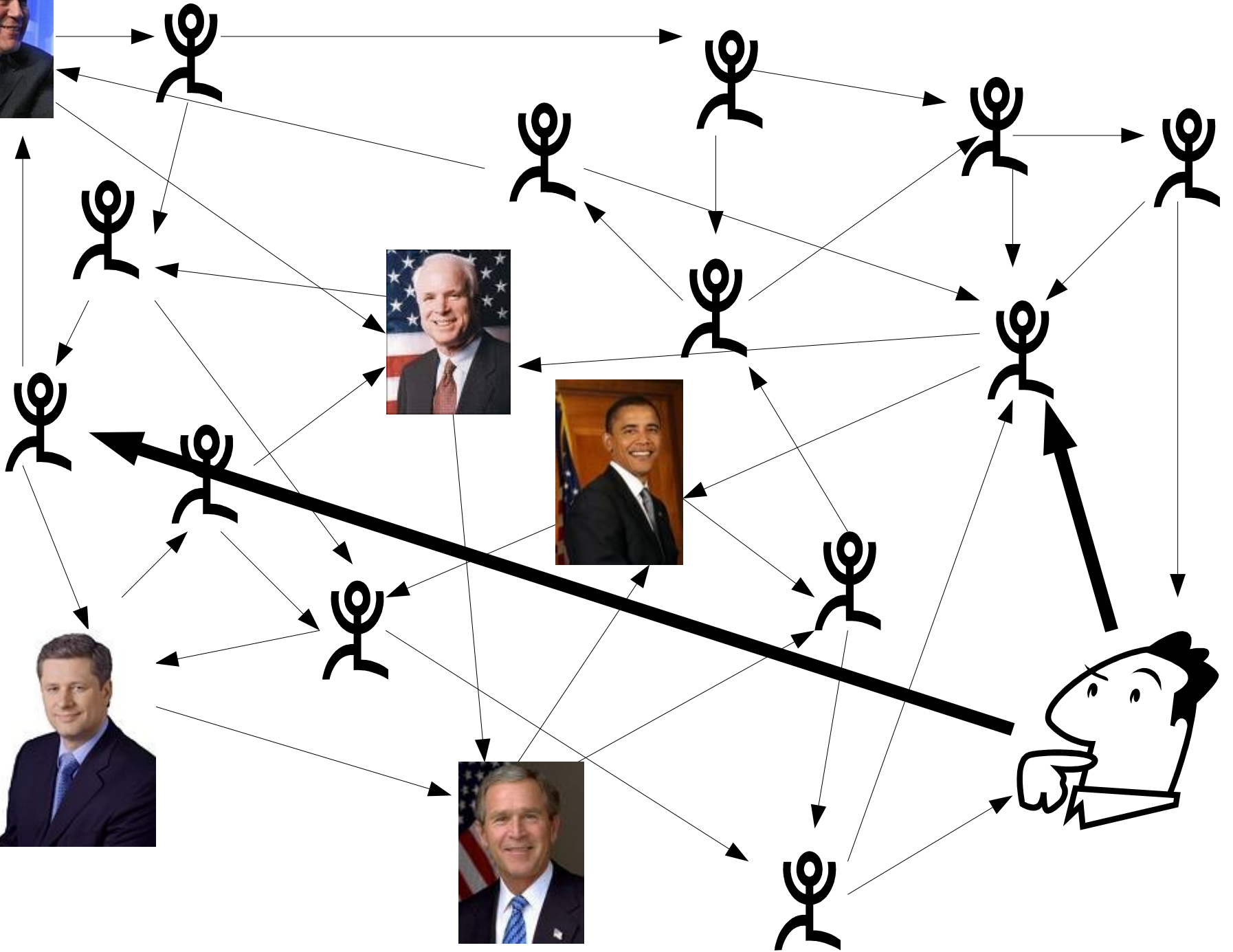
Nikolaos Laoutaris (Telefonica)
Rajmohan Rajaraman (Northeastern)
Ravi Sundaram (Northeastern)
Shang-Hua Teng (Boston Univ.)

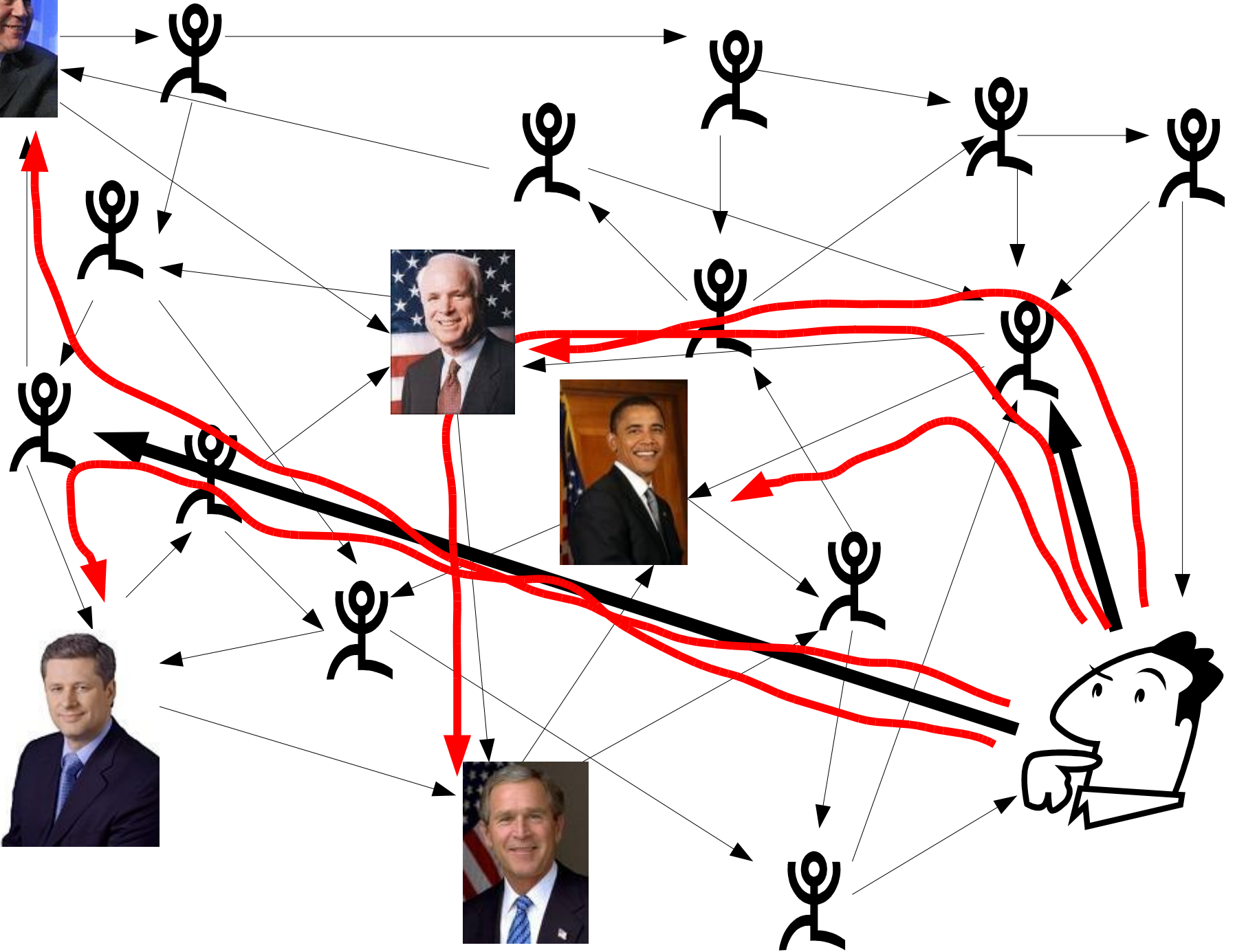


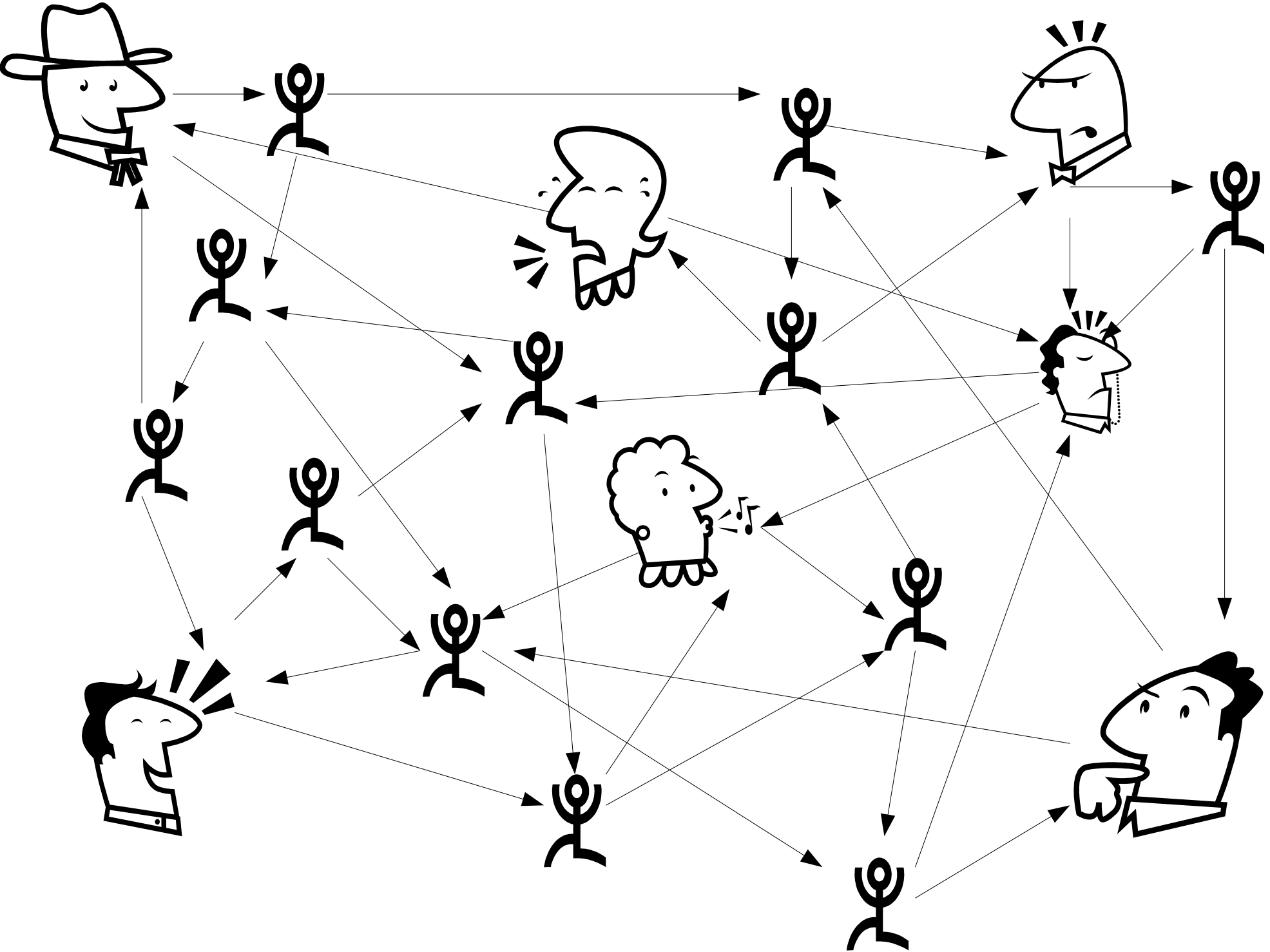


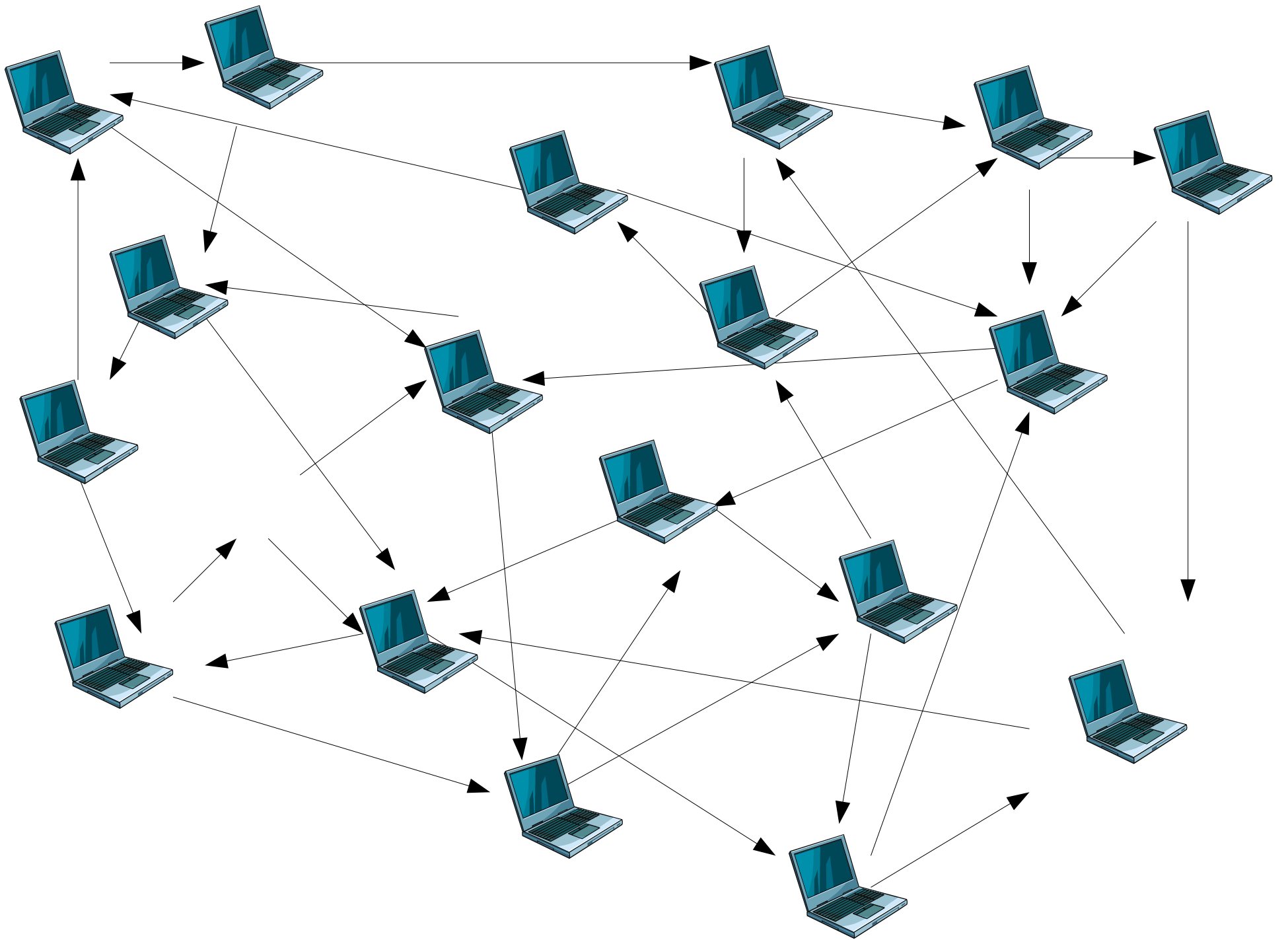












The Model

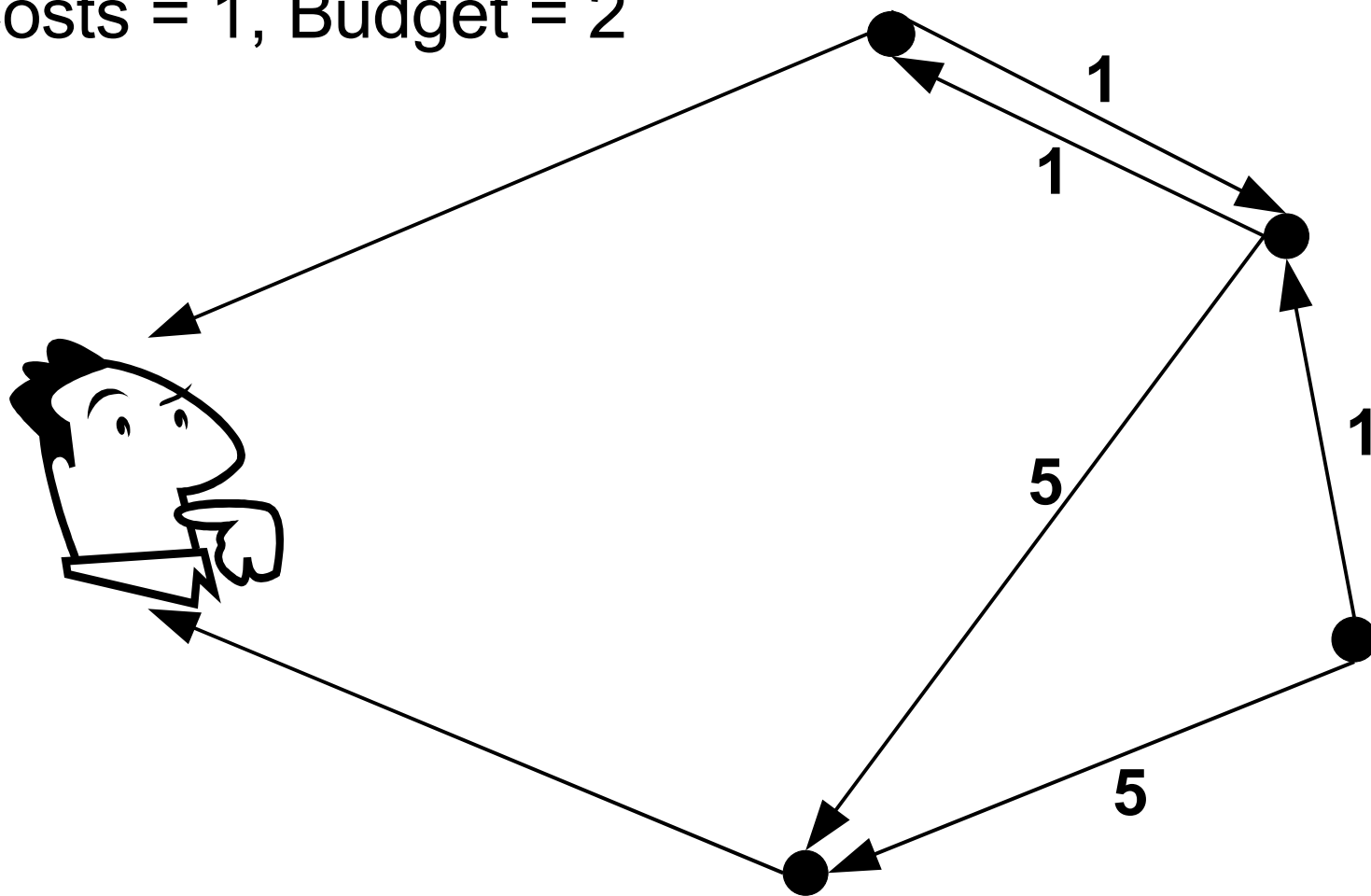
- Number of nodes
- Preference for each directed pair of nodes
- Link cost for each pair of nodes
- Budget of allowed link cost per node, $k(v)$
- Link length between each pair of nodes
- Each node v spends $\leq k(v)$ on links to minimize

$$\sum_{\text{other nodes}} (\text{preference} * \text{shortest path distance})$$

↑ or disconnection penalty if no path exists.

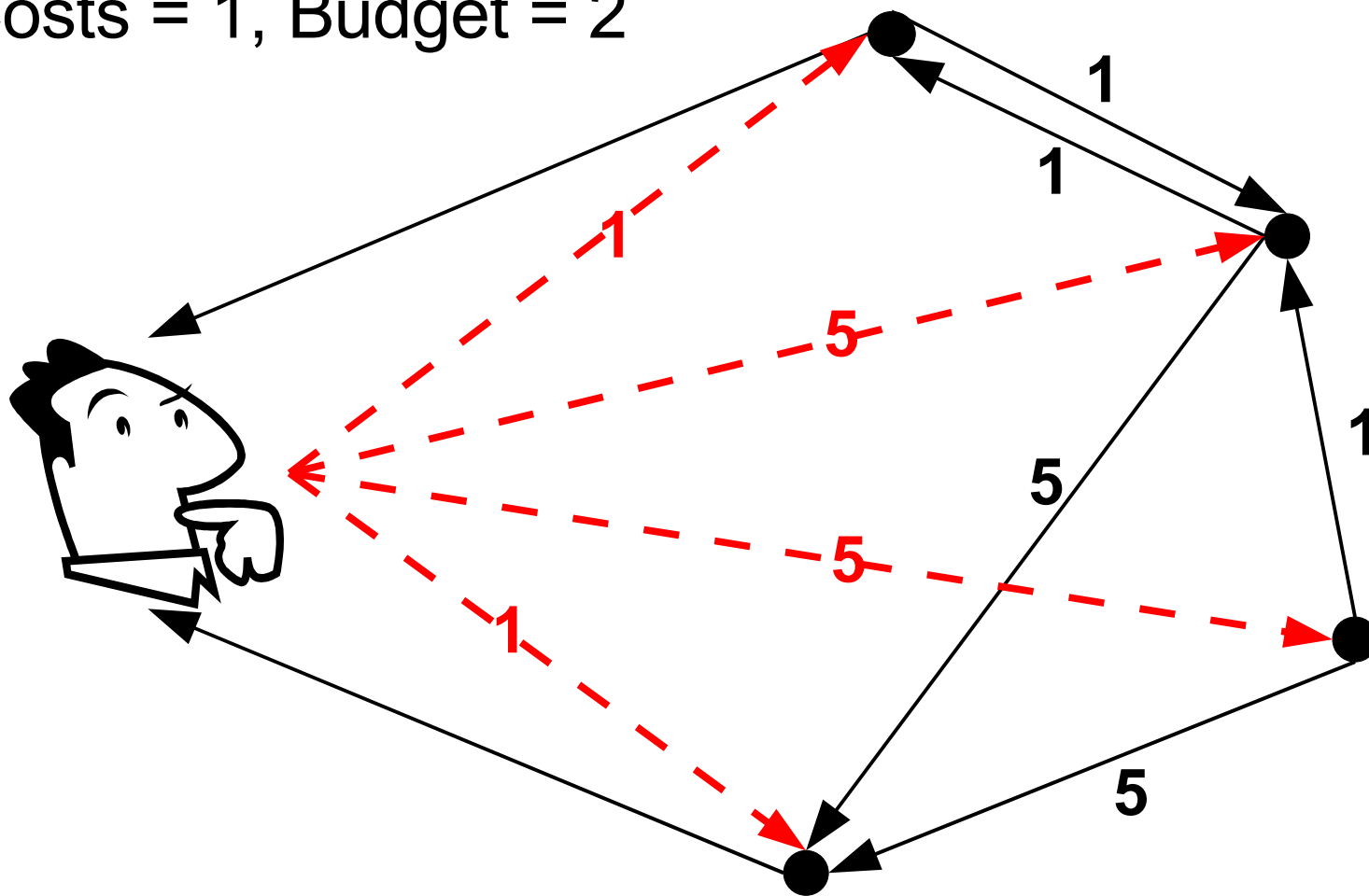
Example

Costs = 1, Budget = 2



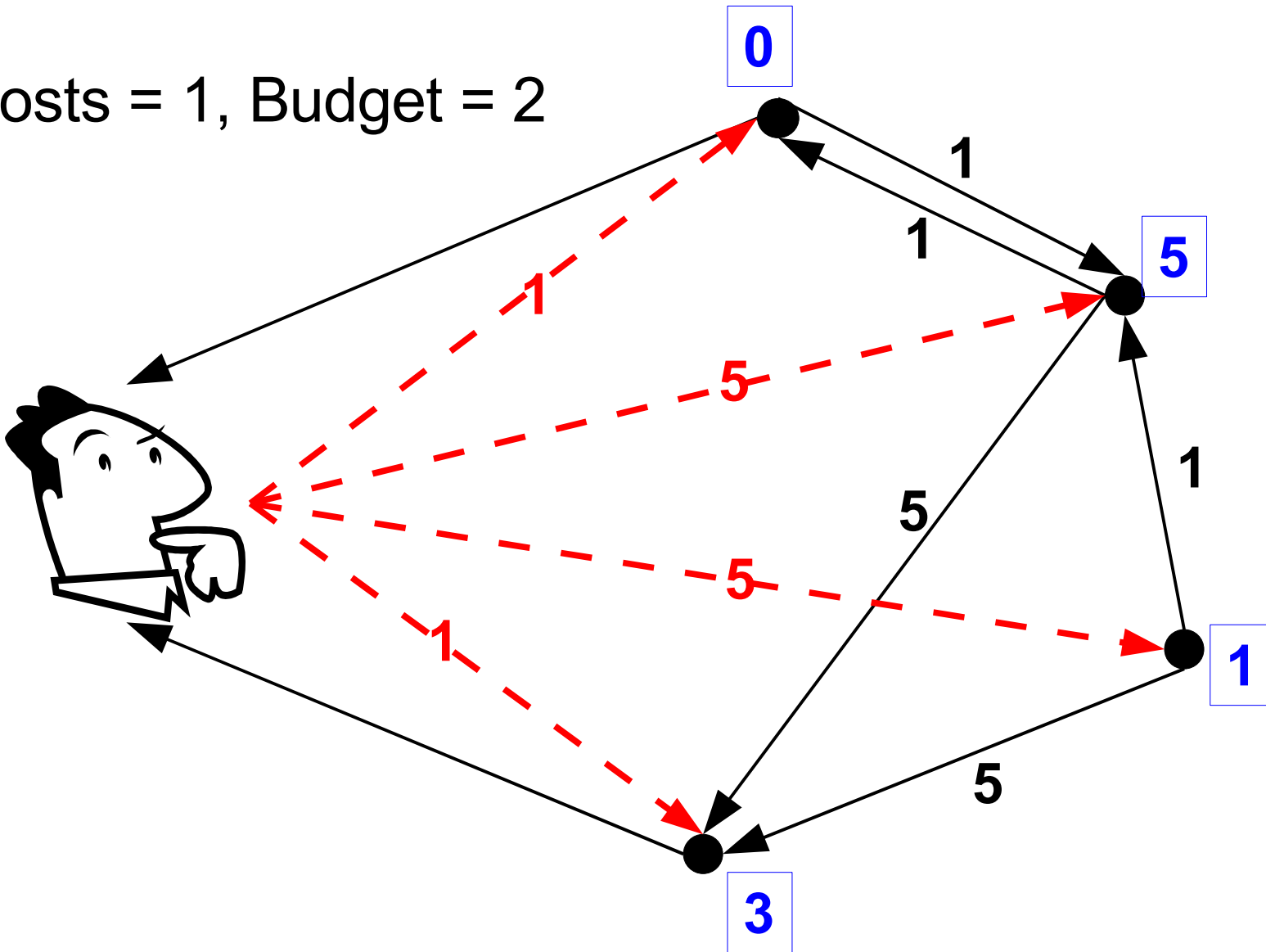
Example

Costs = 1, Budget = 2



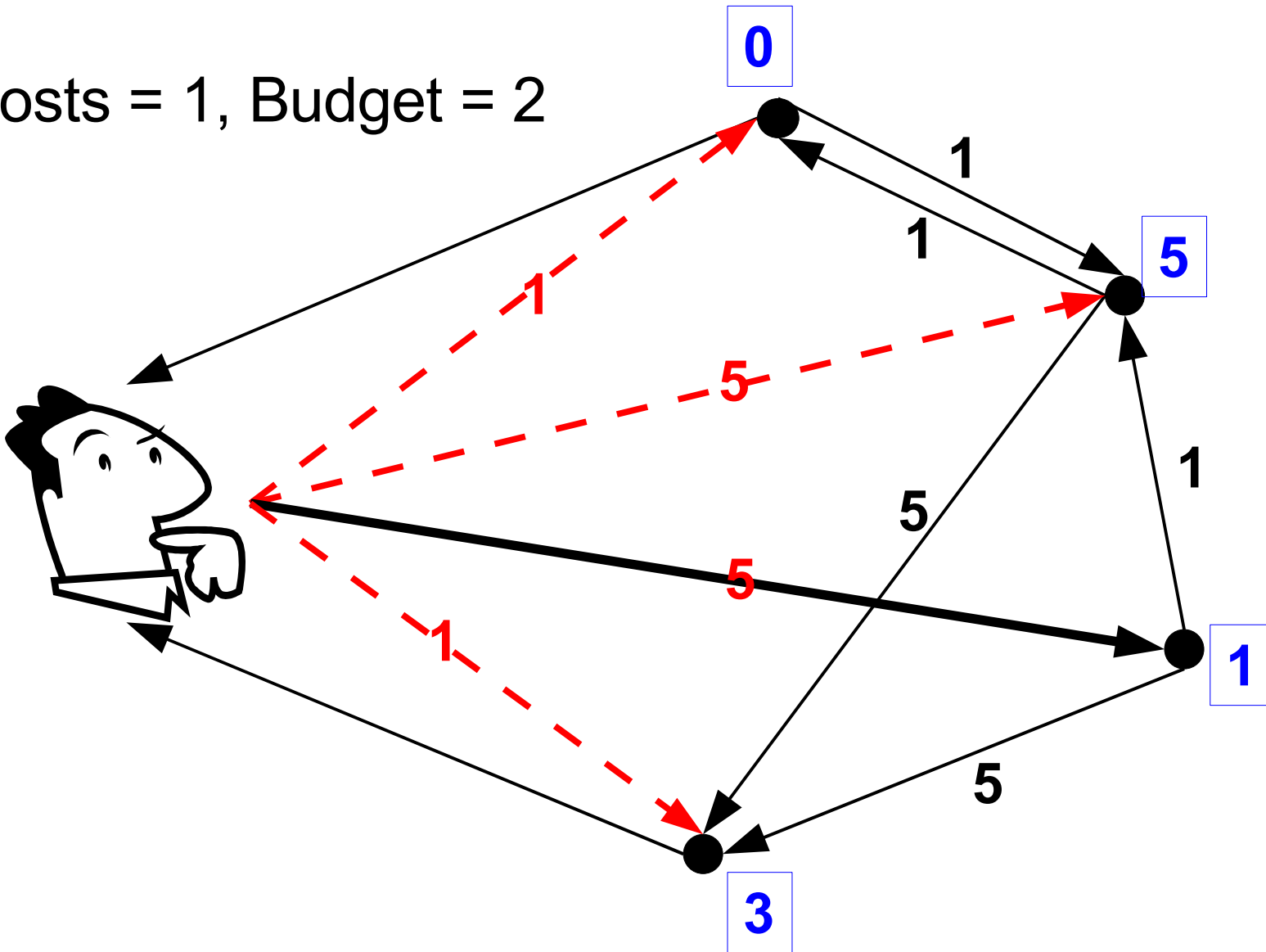
Example

Costs = 1, Budget = 2



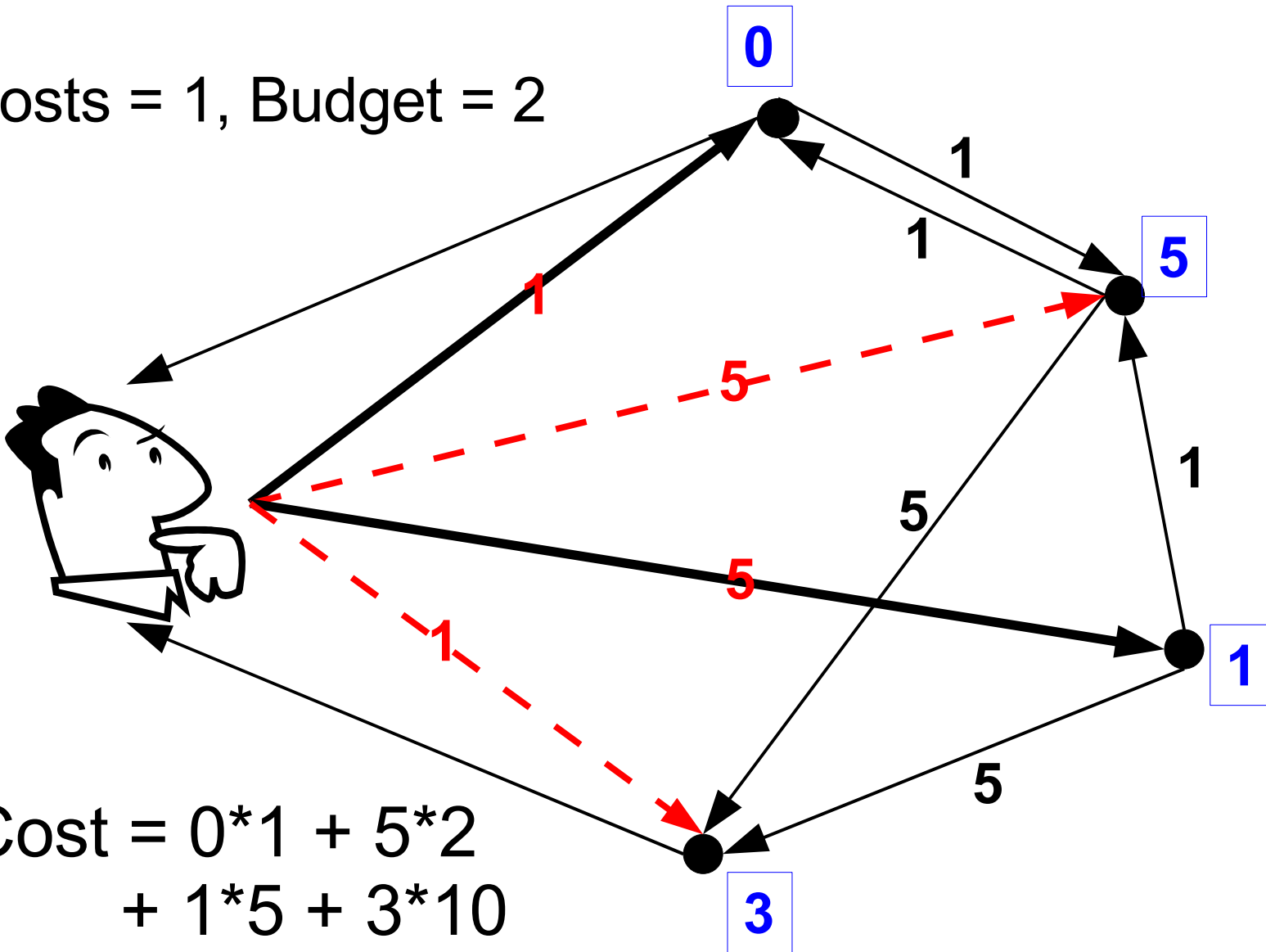
Example

Costs = 1, Budget = 2



Example

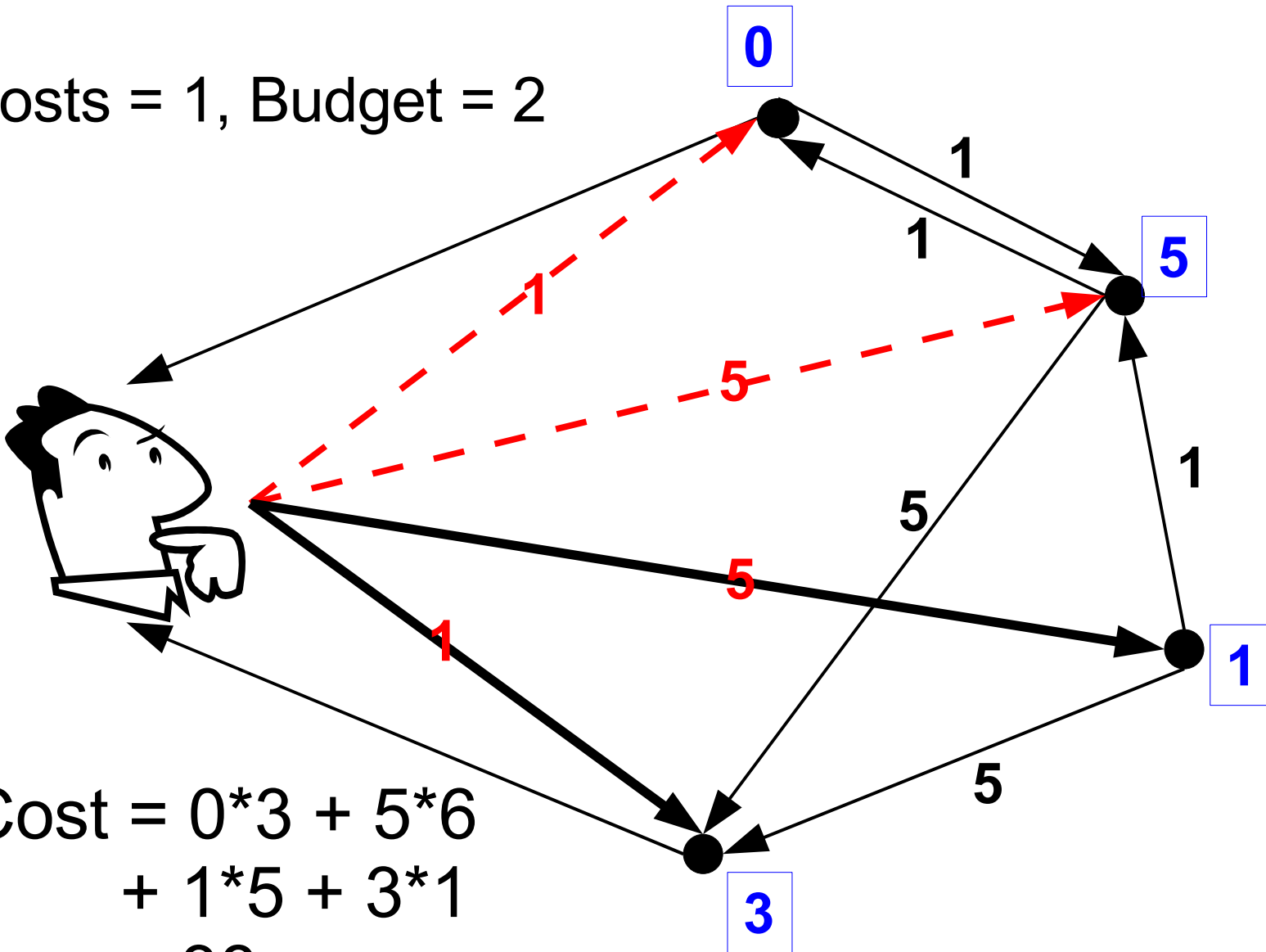
Costs = 1, Budget = 2



$$\begin{aligned} \text{Cost} &= 0 \cdot 1 + 5 \cdot 2 \\ &+ 1 \cdot 5 + 3 \cdot 10 \\ &= 45 \end{aligned}$$

Example

Costs = 1, Budget = 2



$$\begin{aligned} \text{Cost} &= 0 \cdot 3 + 5 \cdot 6 \\ &+ 1 \cdot 5 + 3 \cdot 1 \\ &= 38 \end{aligned}$$

The Model

- Number of nodes
- Preference for each directed pair of nodes
- Link cost for each pair of nodes
- Budget of allowed link cost per node, $k(v)$
- Link length between each pair of nodes
- Each node v spends $\leq k(v)$ on links to minimize

$$\sum_{\text{other nodes}} (\text{preference} * \text{shortest path distance})$$

↑ or disconnection penalty if no path exists.

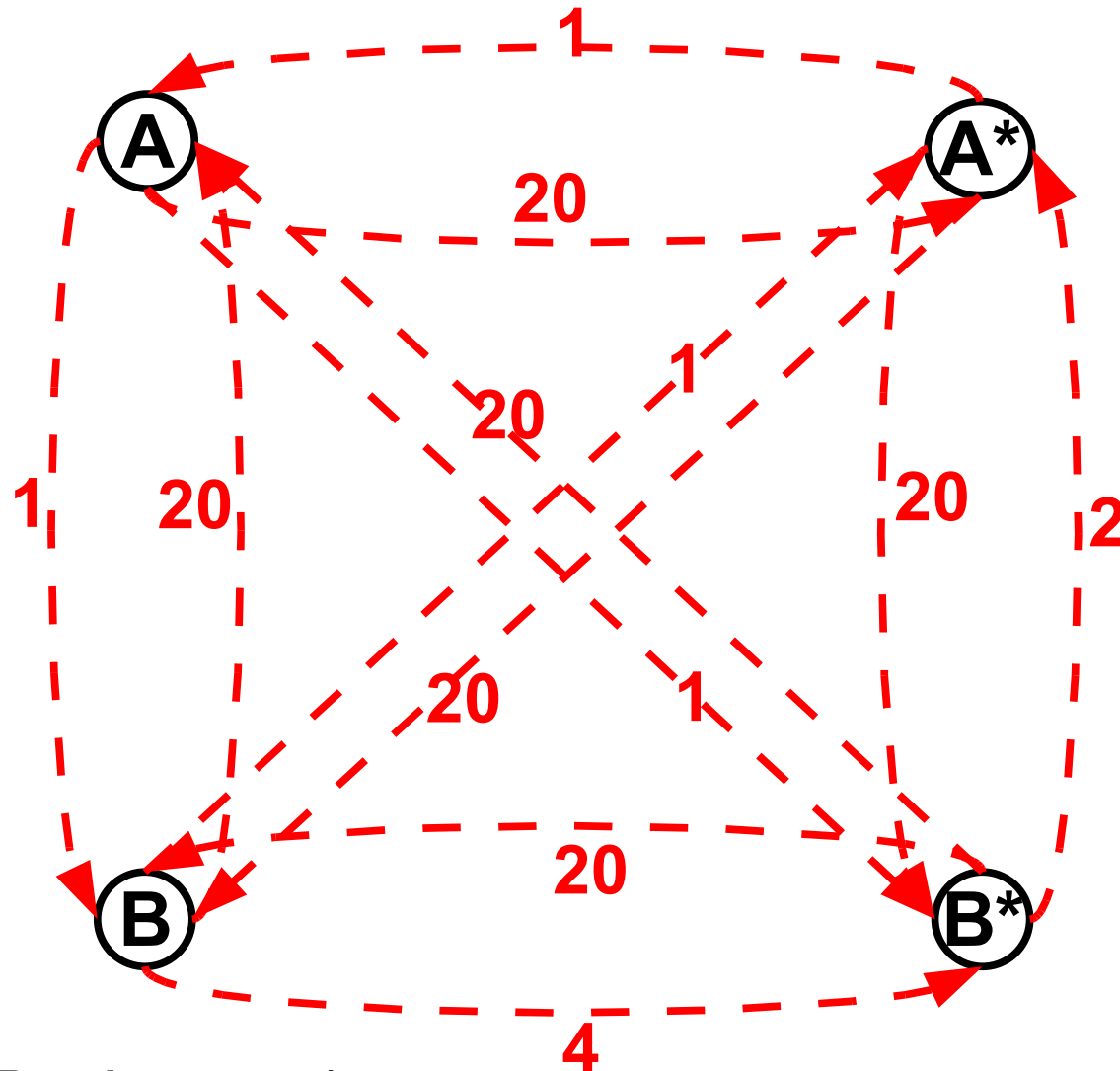
Previous Work

- Fabrikant, Luthra, Maneva, Papadimitriou, Shenker (PODC 2003) – Similar game without a budget for purchasing links.
- Albers, Eilts, Even-Dar, Mansour, Roditty (SODA 2006) and Demaine, Hajiaghavi, Mahini (PODC 2007) - Further work on the same game (without a budget).
- Halevi, Mansour (WINE 2007) – Fabrikant model, with added in preferences.

Our results

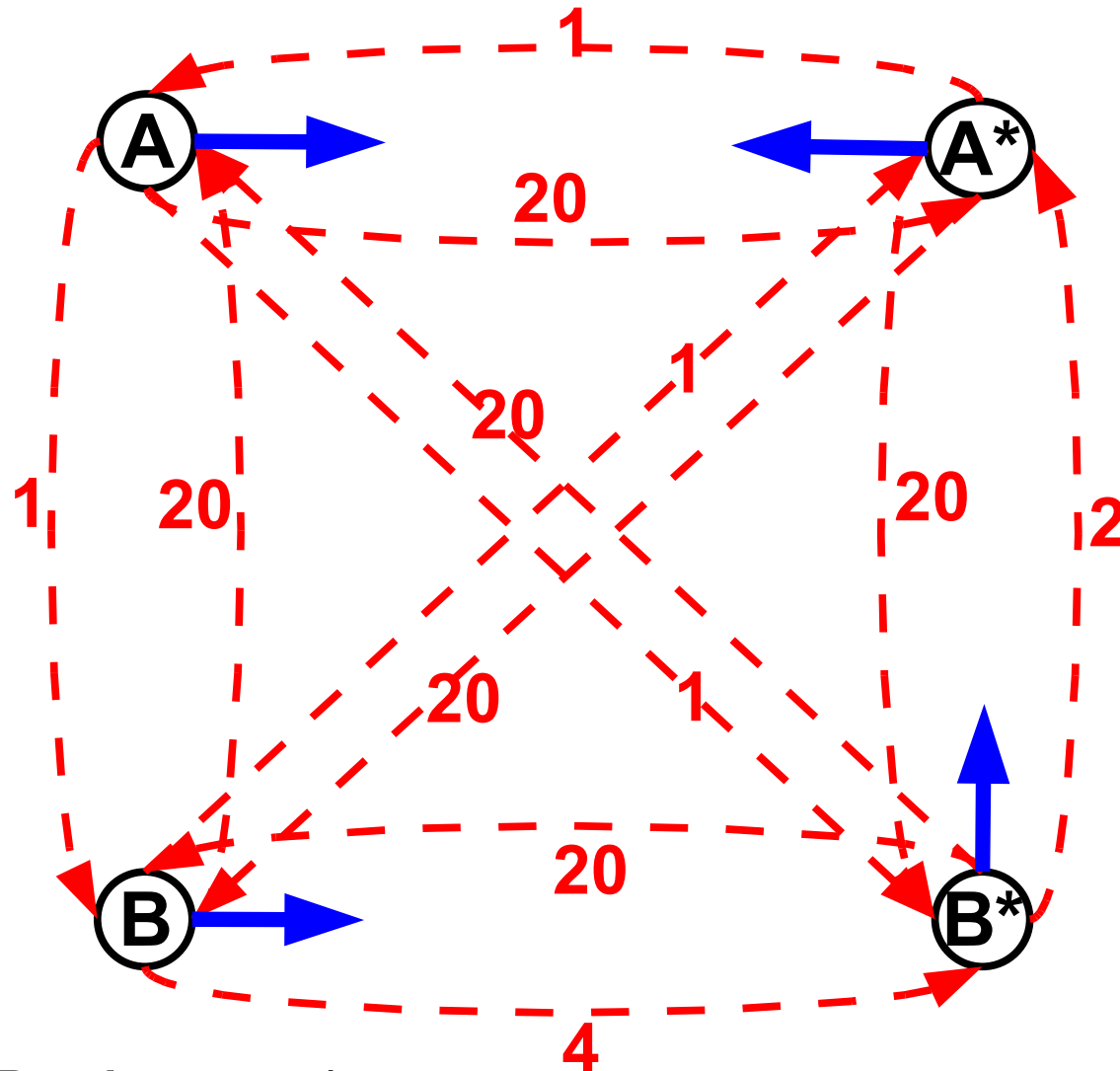
- Pure Nash equilibria do not always exist, and it is NP hard to determine whether they do.
- Uniform BBC games:
 - Pure Nash equilibrium always exists
 - Near-tight bounds on the Price of Anarchy and Price of Stability
 - Dynamics of best response walks
- Parallel results when the utility function is the distance to the furthest other node, not the average distance to all other nodes.

Sometimes no pure Nash equilibrium



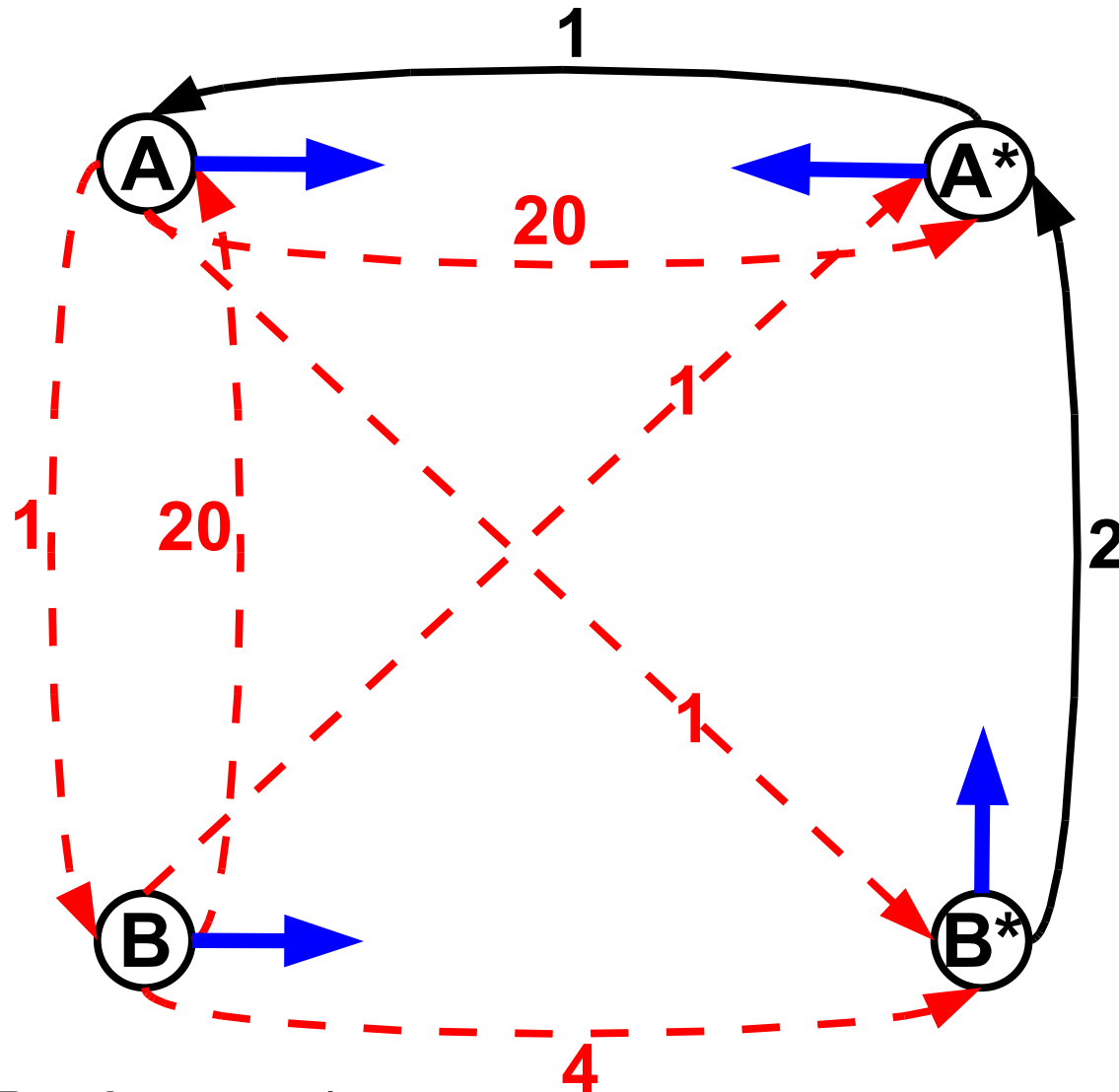
Costs = 1, Budget = 1

Sometimes no pure Nash equilibrium



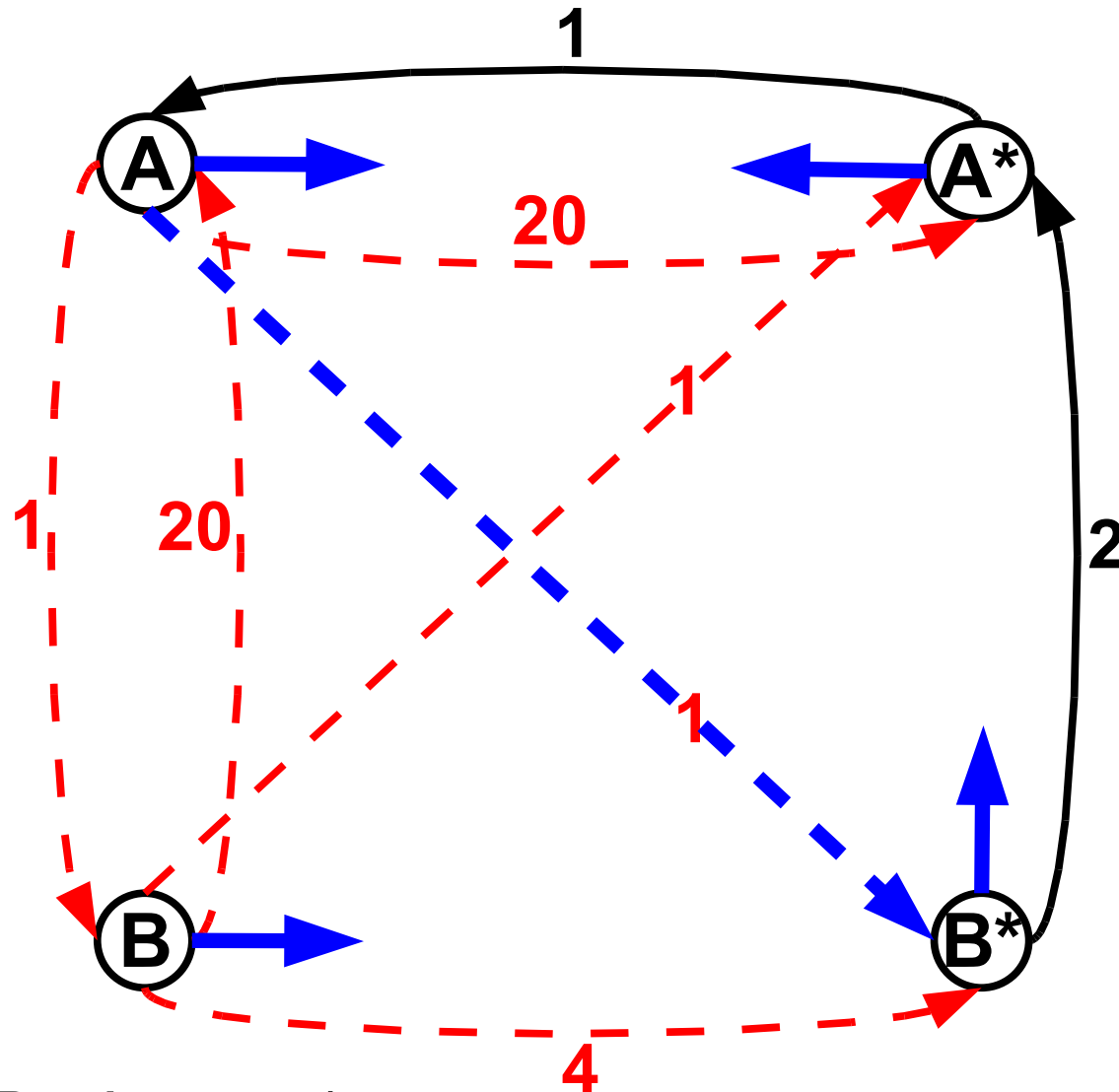
Costs = 1, Budget = 1

Sometimes no pure Nash equilibrium



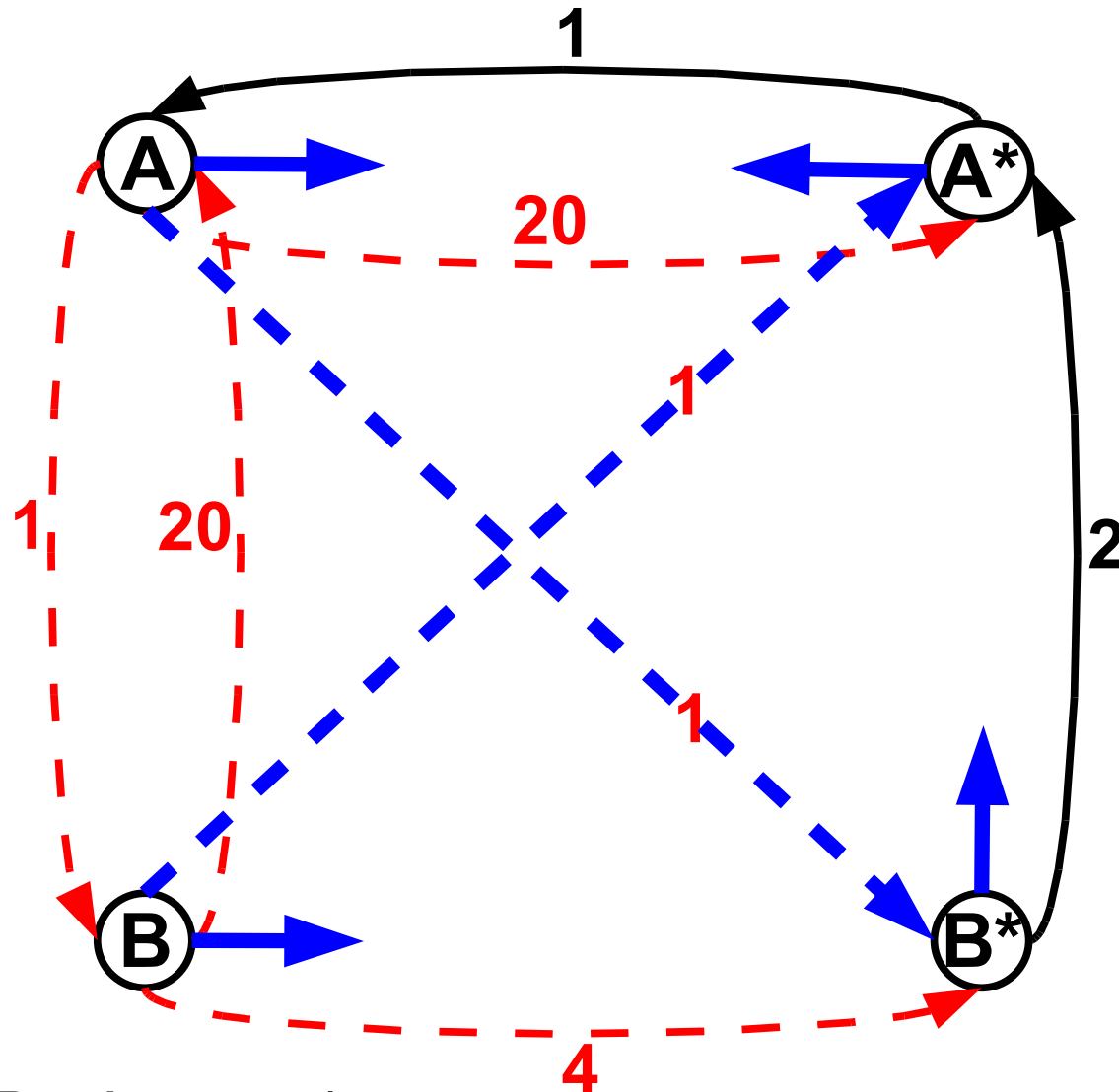
Costs = 1, Budget = 1

Sometimes no pure Nash equilibrium



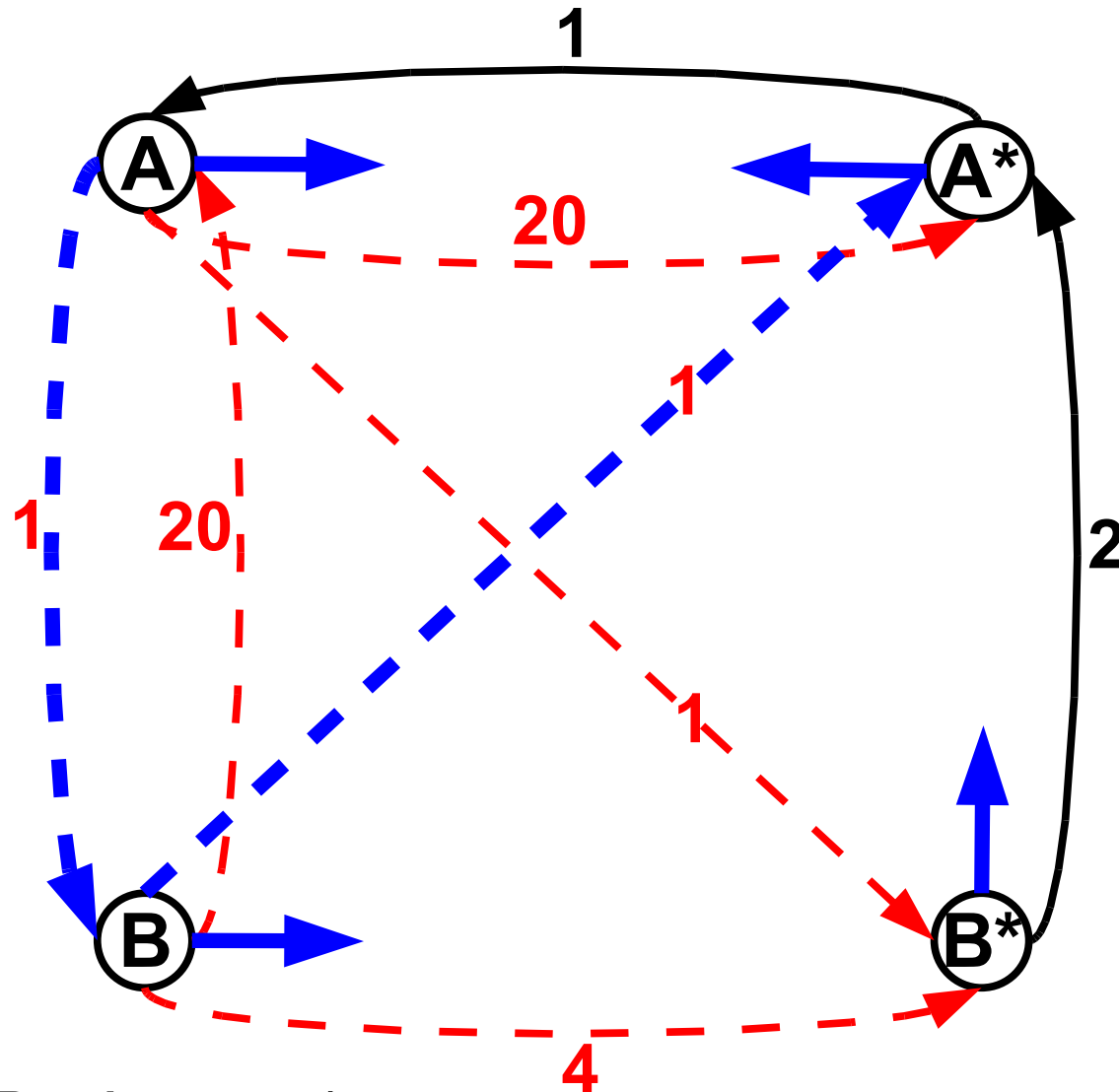
Costs = 1, Budget = 1

Sometimes no pure Nash equilibrium



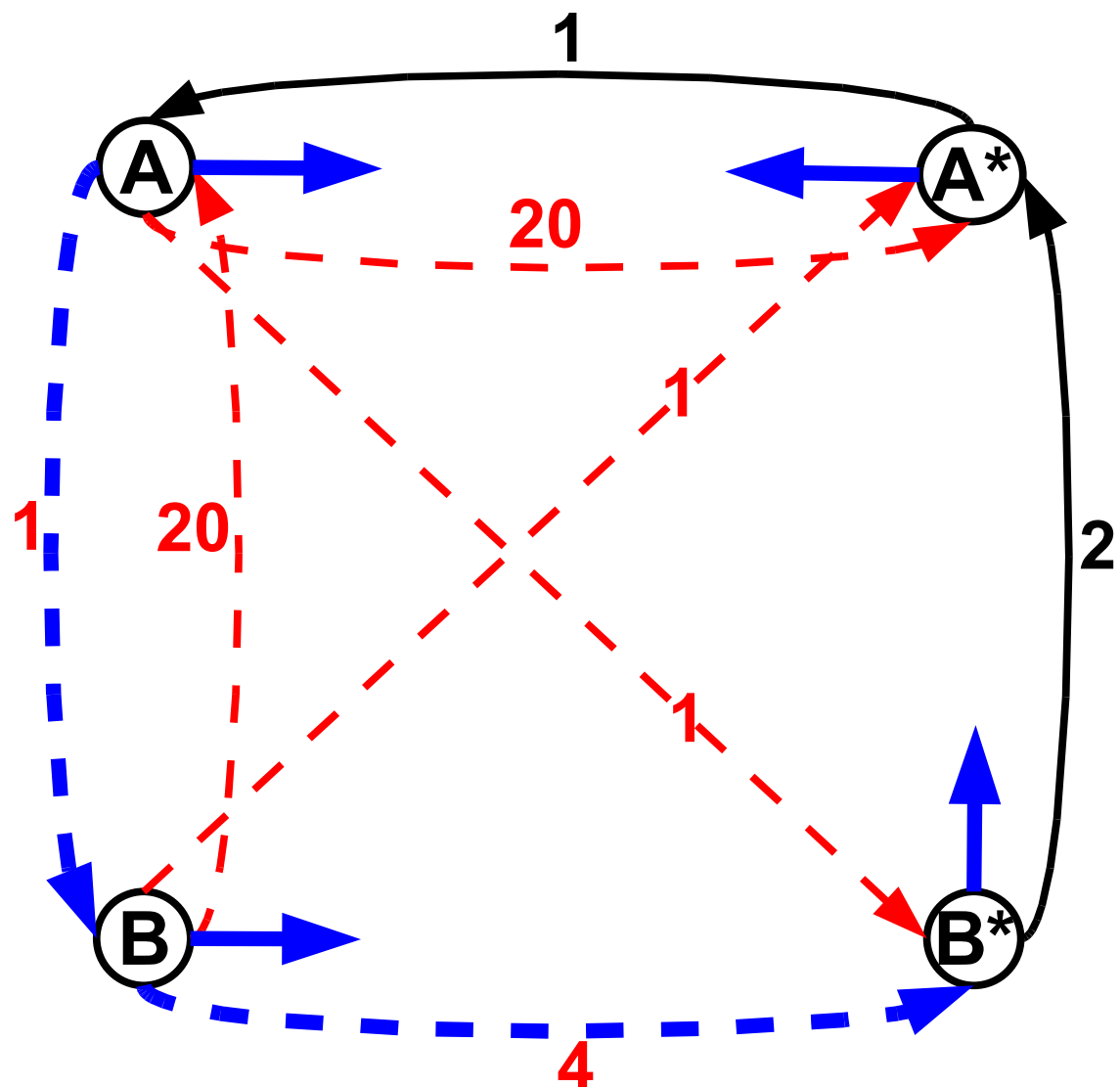
Costs = 1, Budget = 1

Sometimes no pure Nash equilibrium



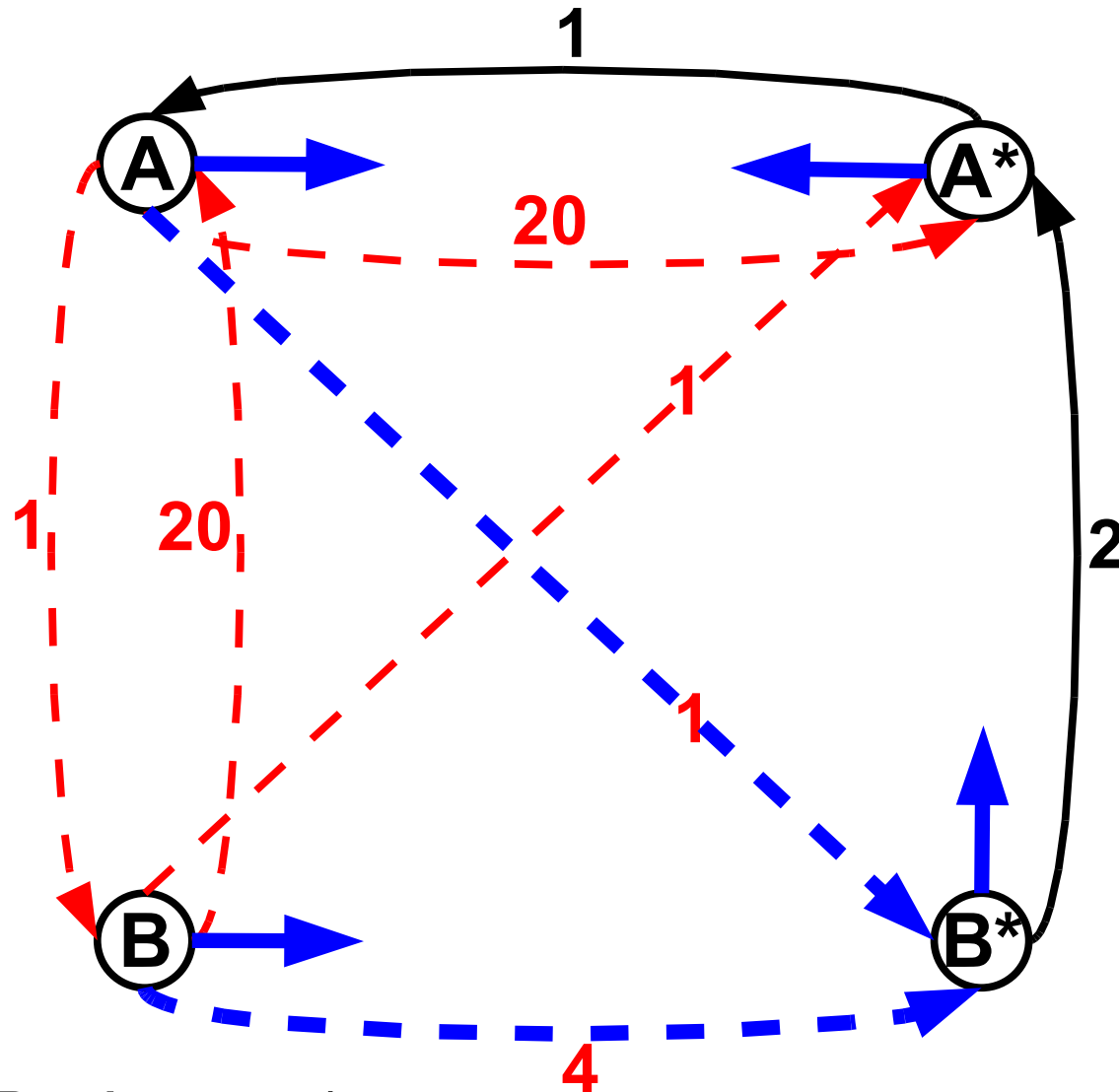
Costs = 1, Budget = 1

Sometimes no pure Nash equilibrium



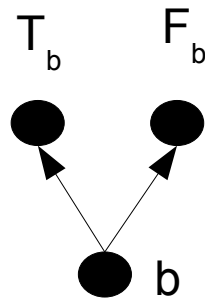
Costs = 1, Budget = 1

Sometimes no pure Nash equilibrium



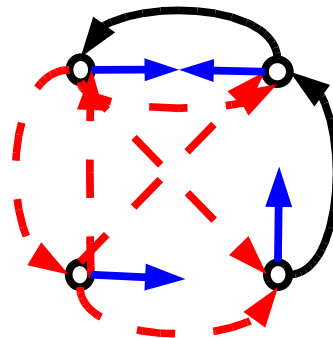
Costs = 1, Budget = 1

NP hard to determine existence of pure Nash equilibrium



Value nodes

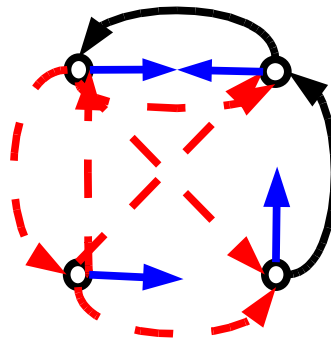
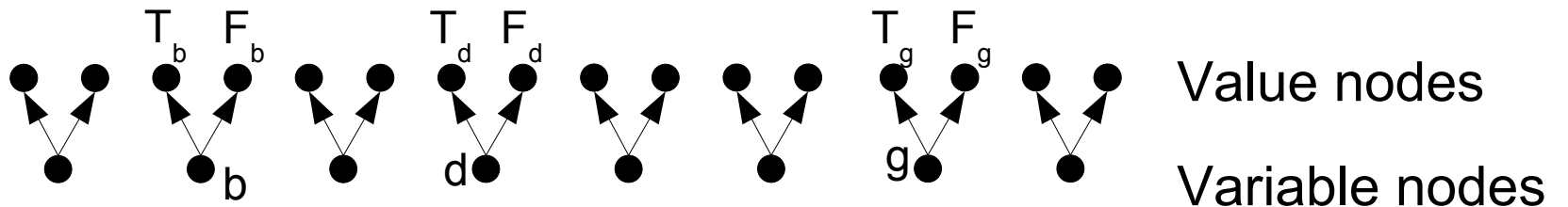
Variable node



Gadget with no Nash equilibrium

Reduction from 3-SAT

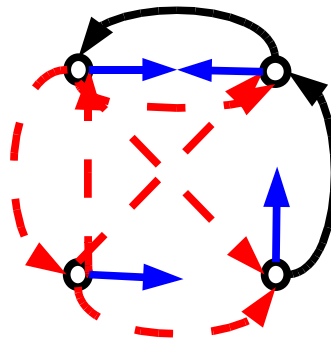
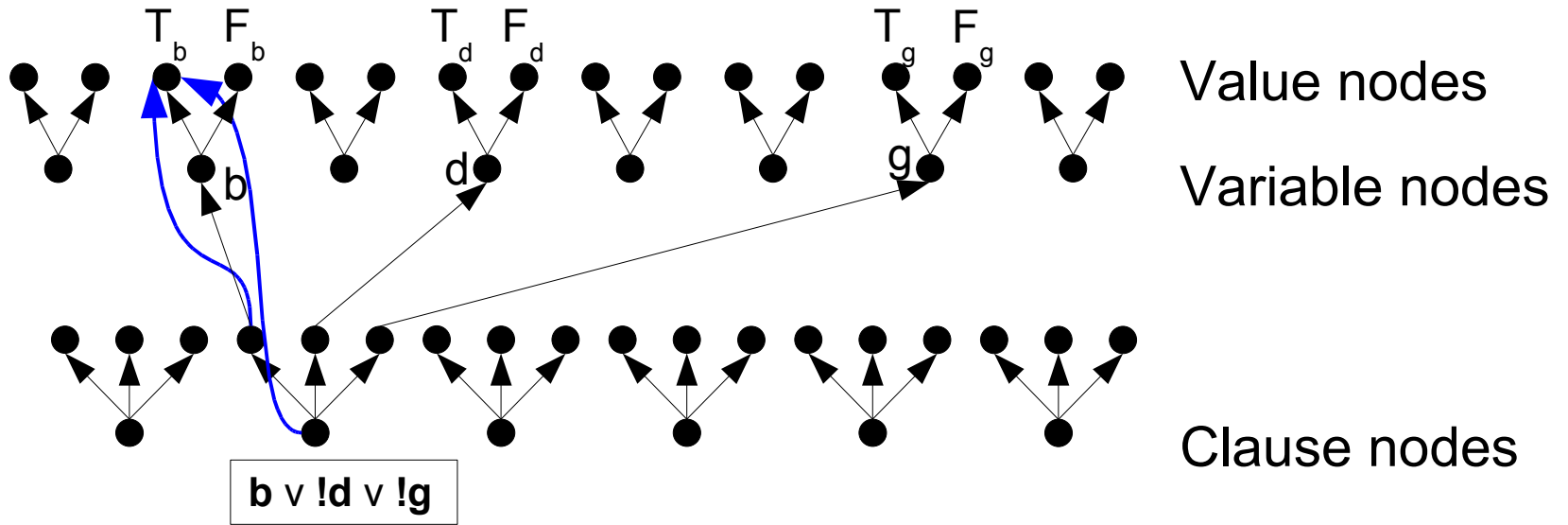
NP hard to determine existence of pure Nash equilibrium



Reduction from 3-SAT

Gadget with no Nash equilibrium

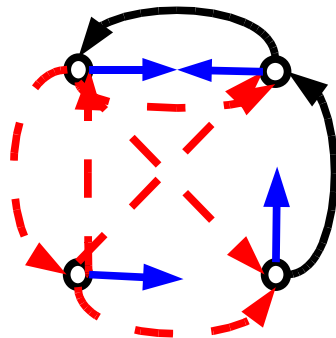
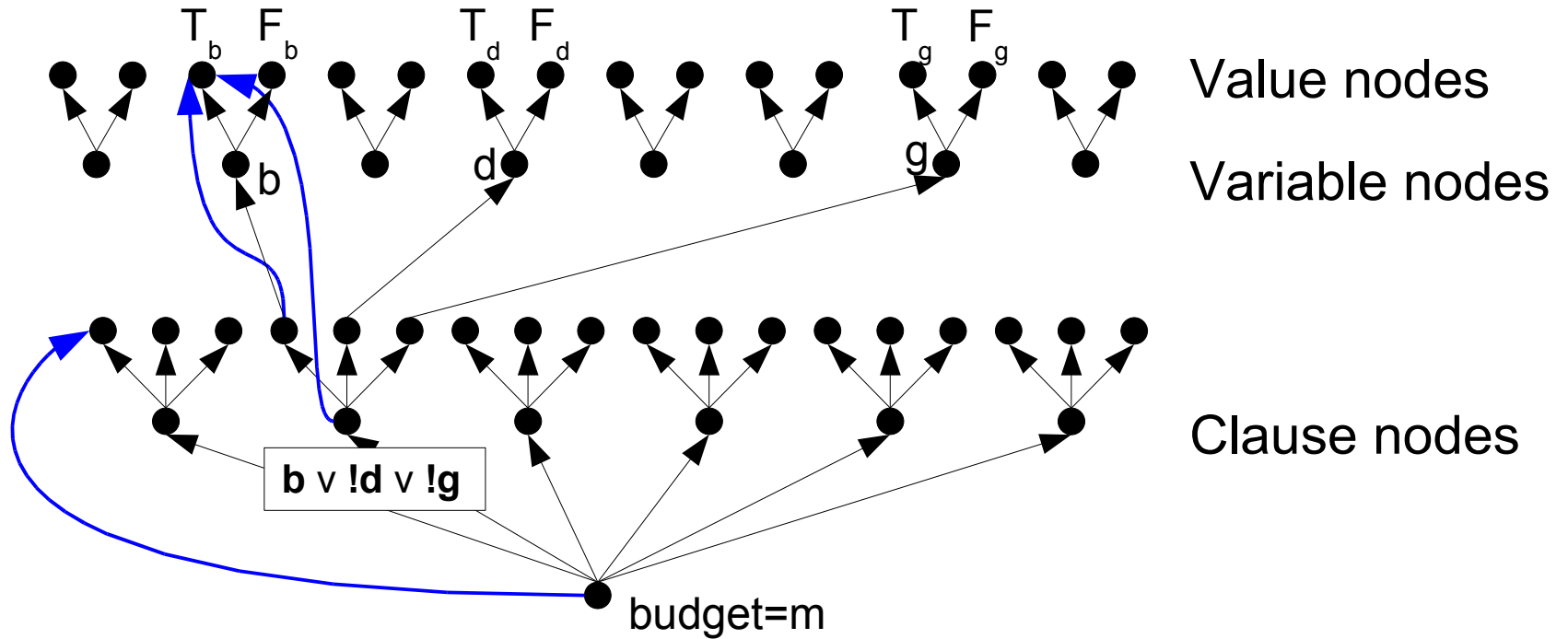
NP hard to determine existence of pure Nash equilibrium



Gadget with no Nash equilibrium

Reduction from 3-SAT

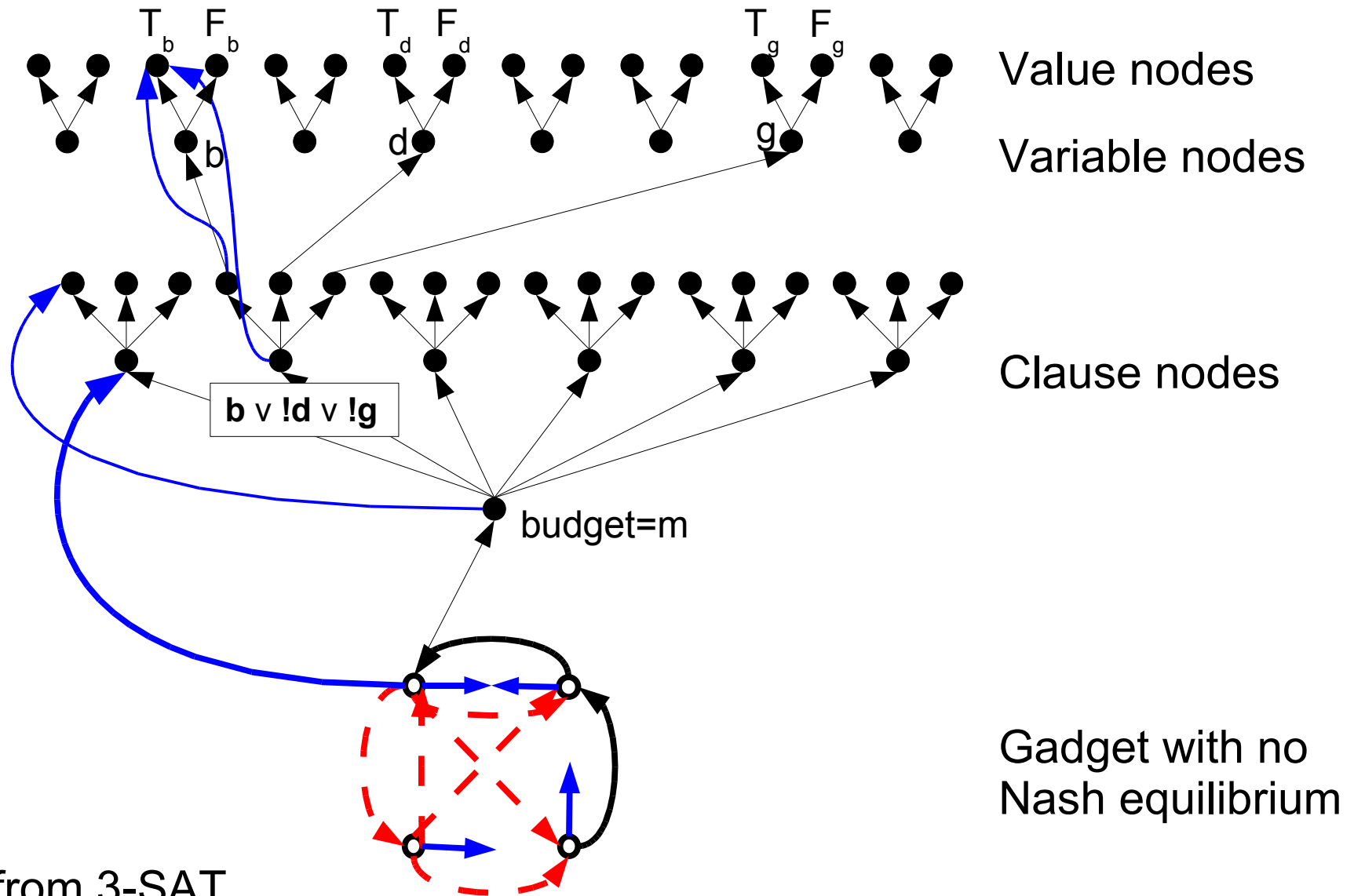
NP hard to determine existence of pure Nash equilibrium



Gadget with no Nash equilibrium

Reduction from 3-SAT

NP hard to determine existence of pure Nash equilibrium

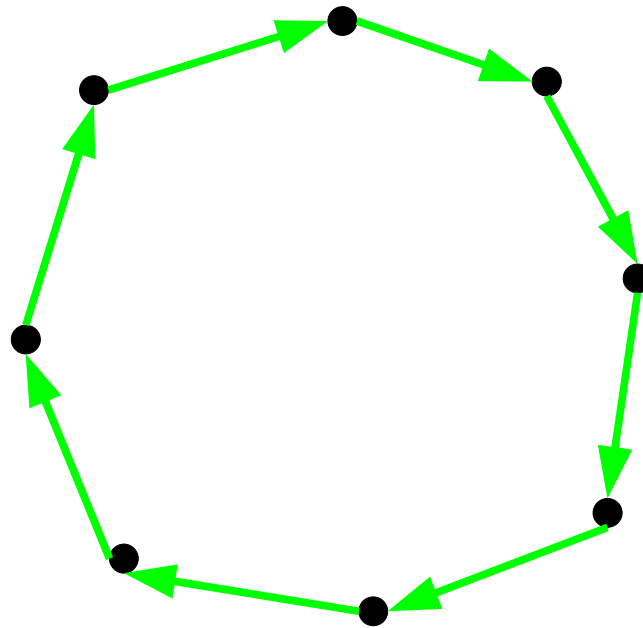


Reduction from 3-SAT

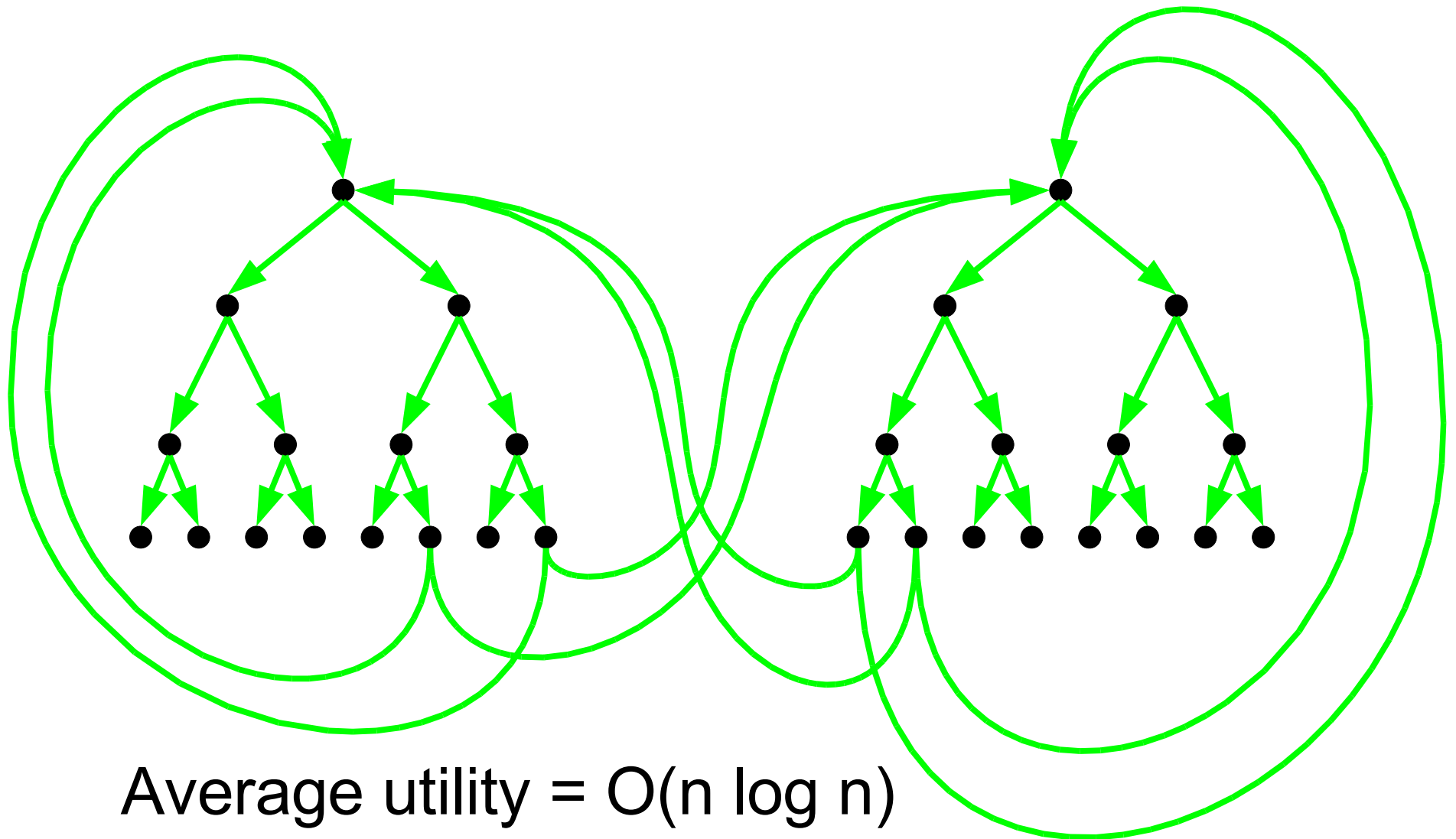
Uniform BBC Games

- Budgets are all k
 - Costs are all 1 (can buy any k links)
 - Lengths are all 1 (hop count path length)
 - Preferences are all 1
-
- (n,k) -uniform games

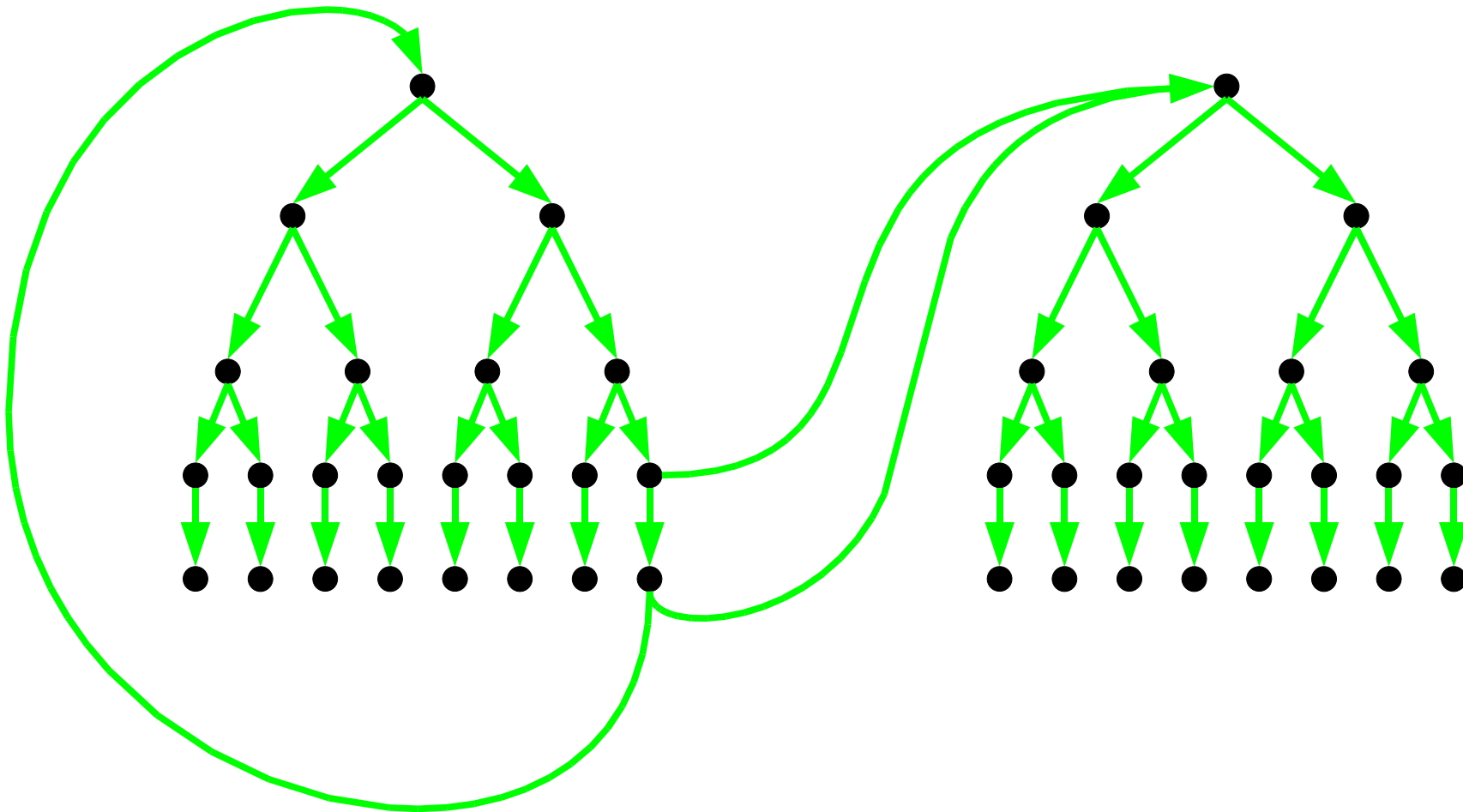
Uniform, $k=1$



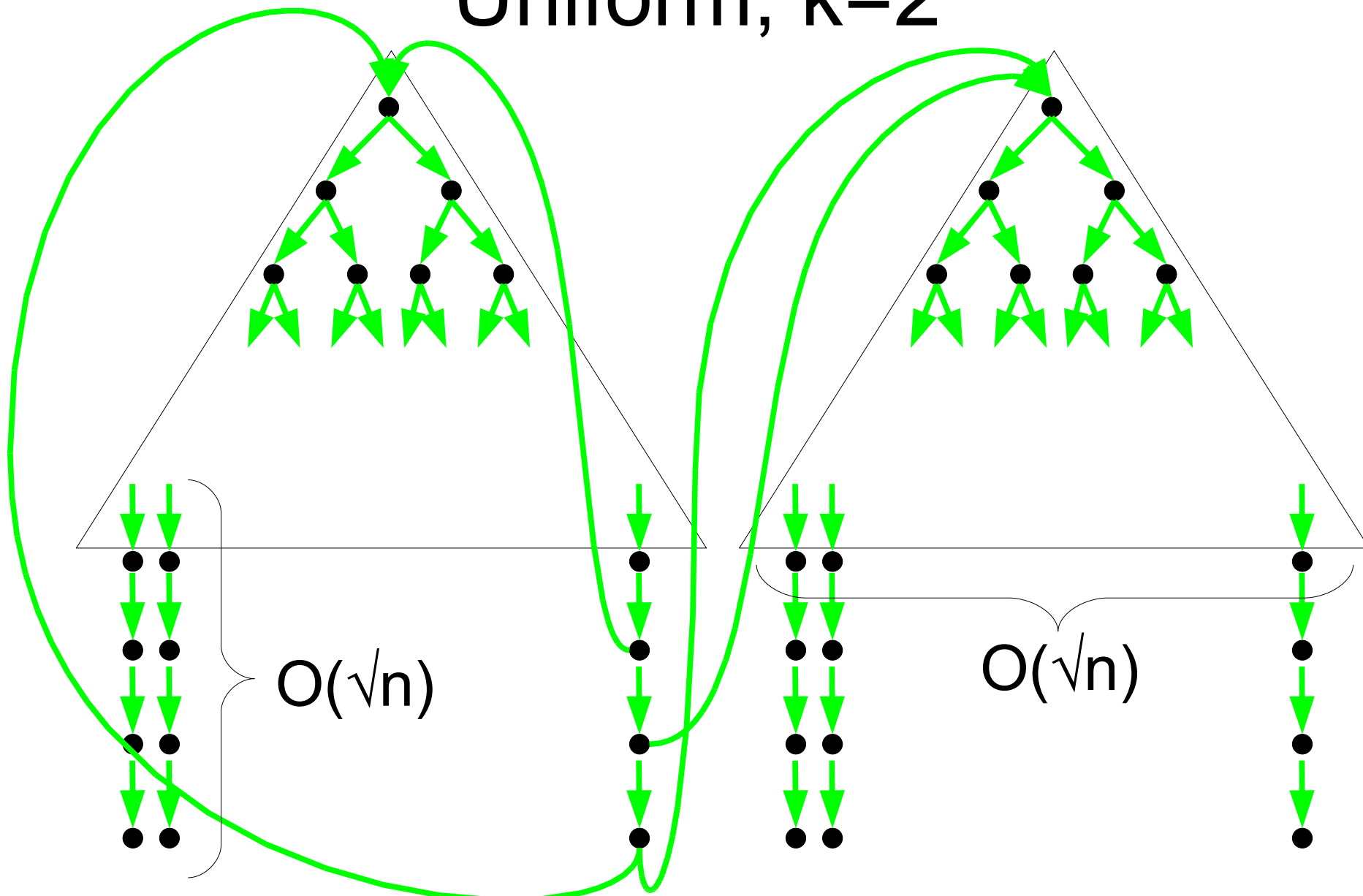
Uniform, $k=2$



Uniform, $k=2$



Uniform, $k=2$

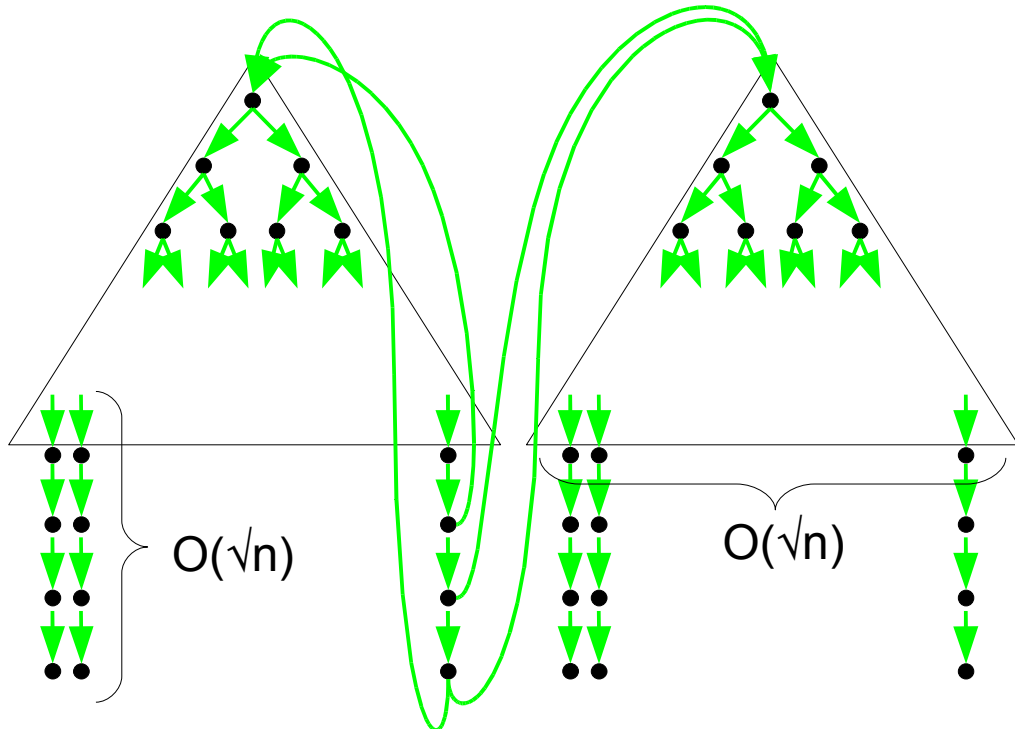


$O(\sqrt{n})$

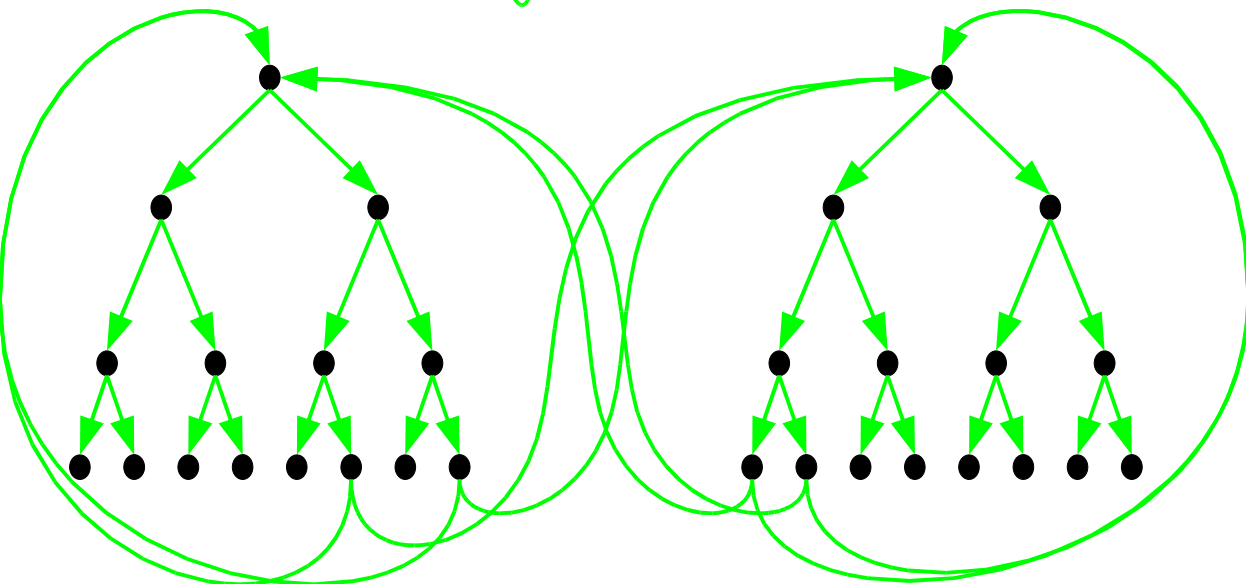
$O(\sqrt{n})$

Average utility = $O(n \sqrt{n})$

Uniform, $k=2$

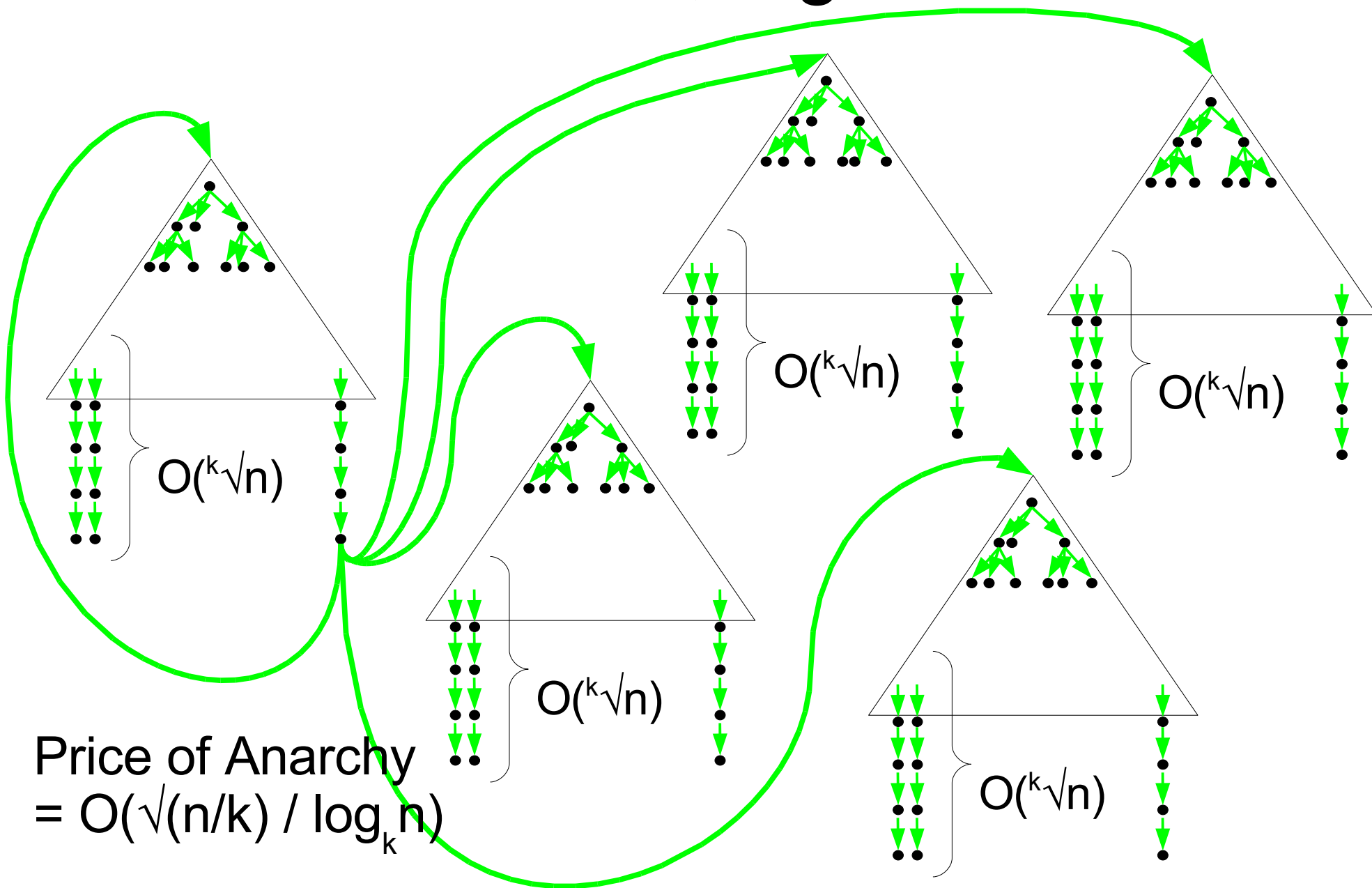


Average utility =
 $O(n \sqrt{n})$

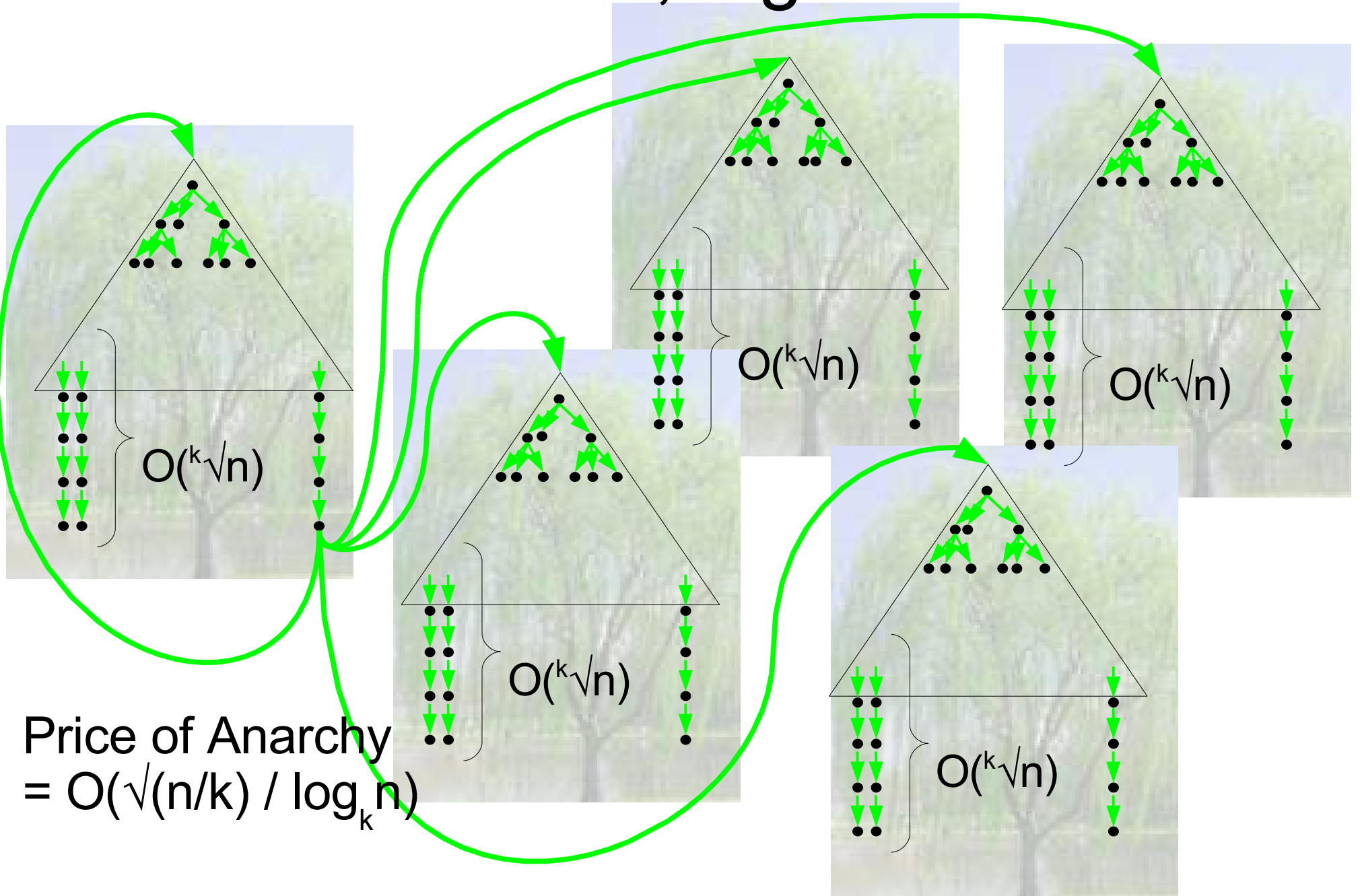


Average utility =
 $O(n \log n)$

Uniform, higher k



Uniform, higher k

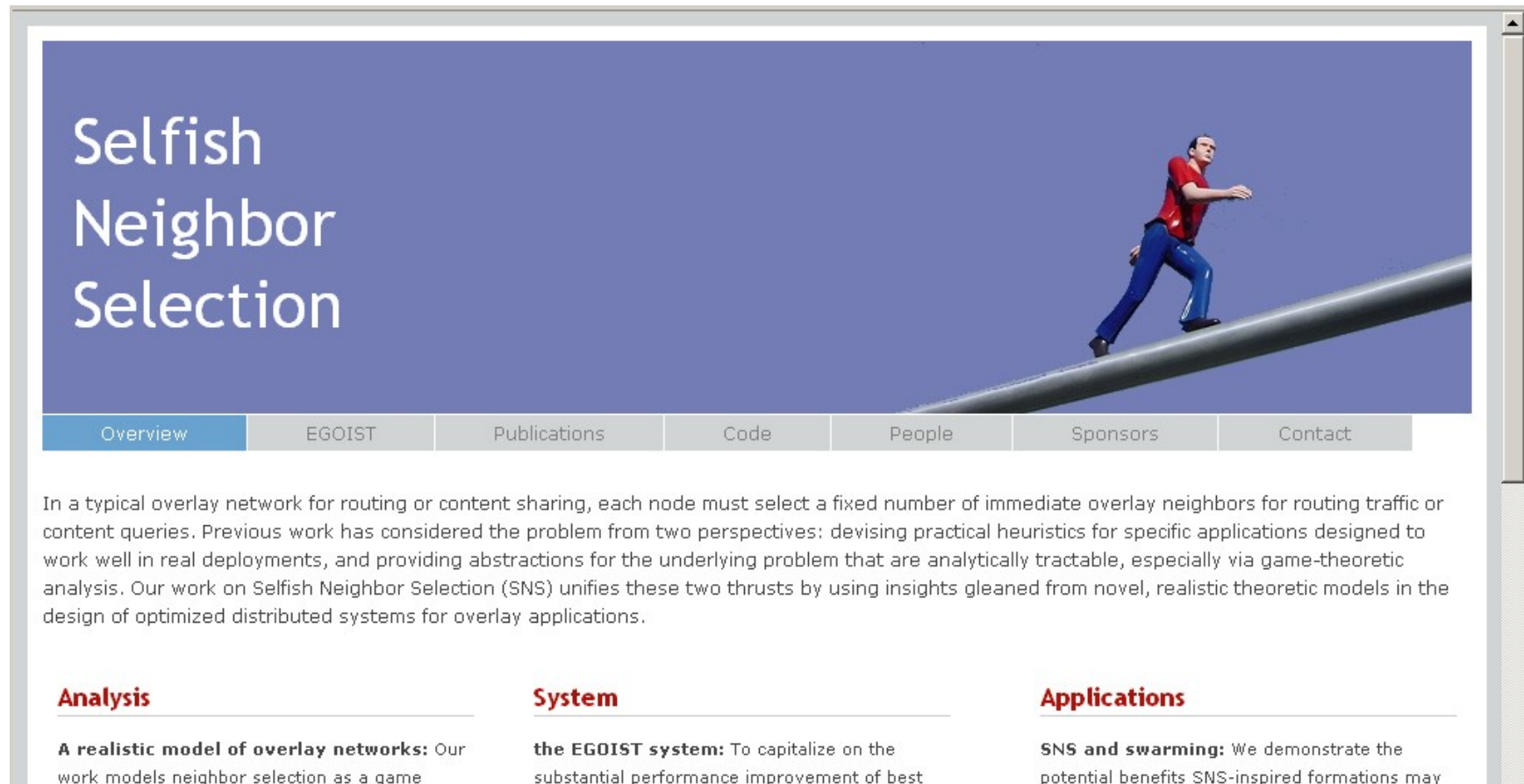


Open Problems

- Is there always a pure Nash equilibrium if only the budget is non-uniform?
- For general BBC games, can we find an approximate equilibrium in polynomial time?
- Convergence via best response walks: will any initial graph converge to a pure Nash equilibrium for uniform BBC games? If so, will it be a “good” equilibrium?
- Tighter bounds on Price of Anarchy
- Same game with undirected graphs

Experimental work on this model

- <http://csr.bu.edu/sns/>



Selfish Neighbor Selection

Overview EGOIST Publications Code People Sponsors Contact

In a typical overlay network for routing or content sharing, each node must select a fixed number of immediate overlay neighbors for routing traffic or content queries. Previous work has considered the problem from two perspectives: devising practical heuristics for specific applications designed to work well in real deployments, and providing abstractions for the underlying problem that are analytically tractable, especially via game-theoretic analysis. Our work on Selfish Neighbor Selection (SNS) unifies these two thrusts by using insights gleaned from novel, realistic theoretic models in the design of optimized distributed systems for overlay applications.

Analysis

A realistic model of overlay networks: Our work models neighbor selection as a game

System

the EGOIST system: To capitalize on the substantial performance improvement of best

Applications

SNS and swarming: We demonstrate the potential benefits SNS-inspired formations may

Smaragdakis, Bestavros, Byers, Laoutaris, Michiardi, Lekakis, Roussopoulos