

Social Instruments for Robust Convention Emergence

Daniel Villatoro, Jordi Sabater-Mir and Sandip Sen

What are conventions?

► Conventional Norms

- Solve **coordination problems** where there is no conflicts between the individual and the collective interests.

	Agent 1 chooses A	Agent 1 chooses B
Agent 2 chooses A	5 for Agent 1 5 for Agent 2	0 for Agent 1 0 for Agent 2
Agent 2 chooses B	0 for Agent 1 0 for Agent 2	5 for Agent 1 5 for Agent 2

Conventional Norms

Player B drives
on the **Left**



Player A drives
on the **Left**

Player B drives
on the **Right**

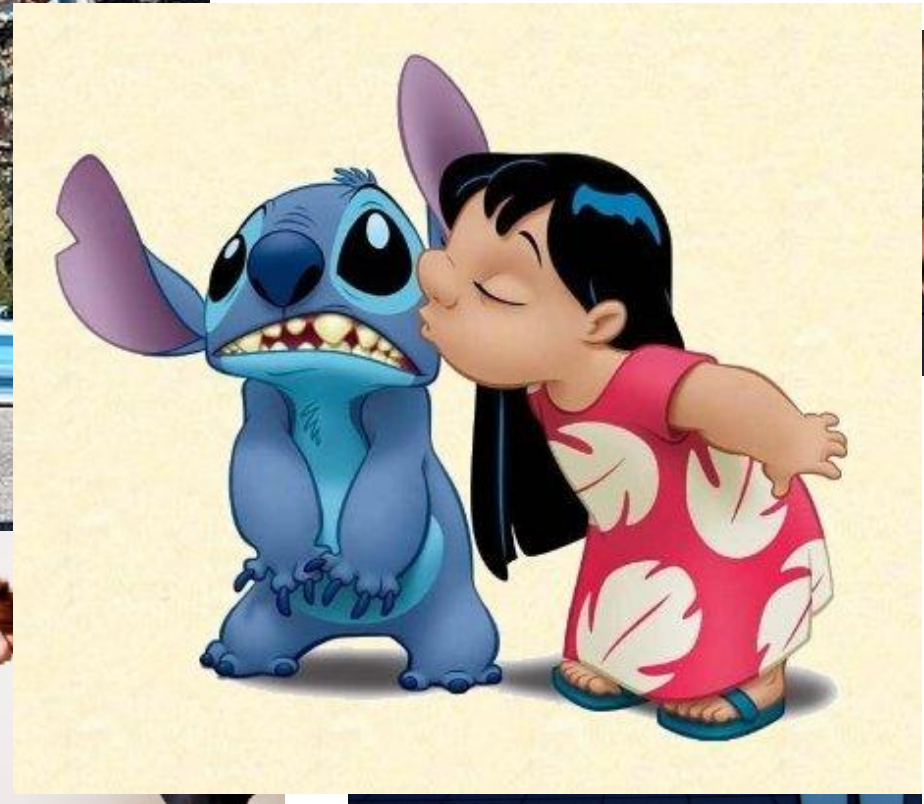


Player A drives
on the **Right**



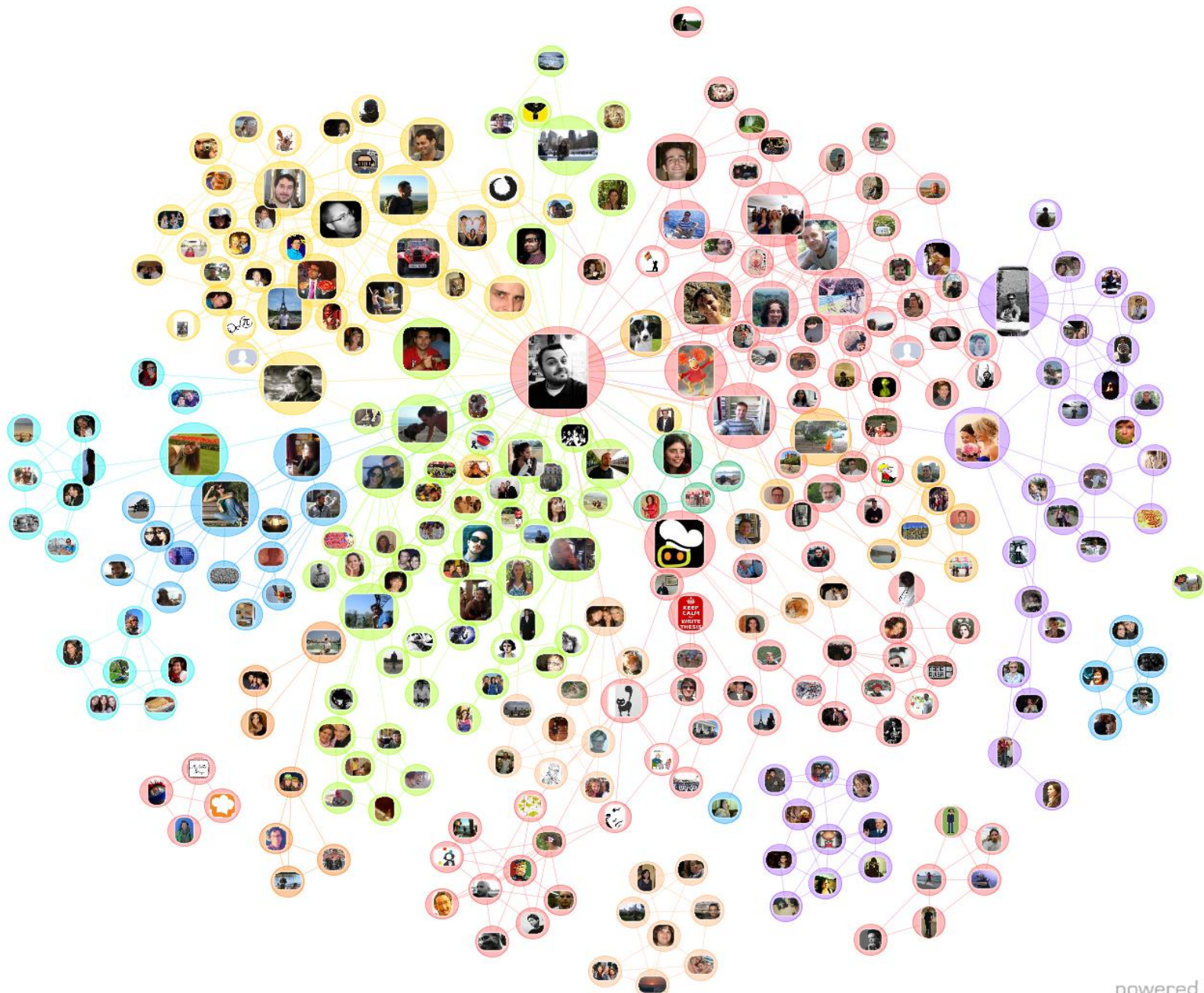
Convention Emergence

- ▶ E.g. Greeting



Basics of Convention Emergence

- ▶ Agents located in a network.
 - Network defines interactions.
- ▶ Equally beneficial conventions.
- ▶ No initial preference.
- ▶ Social Learning
 - Learning by interacting without pre-organizational communication.
- ▶ No access to private variables.
 - Only visible and public information.



Lingliang

dvillatoro@iia.csic.es

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ANALYTICS

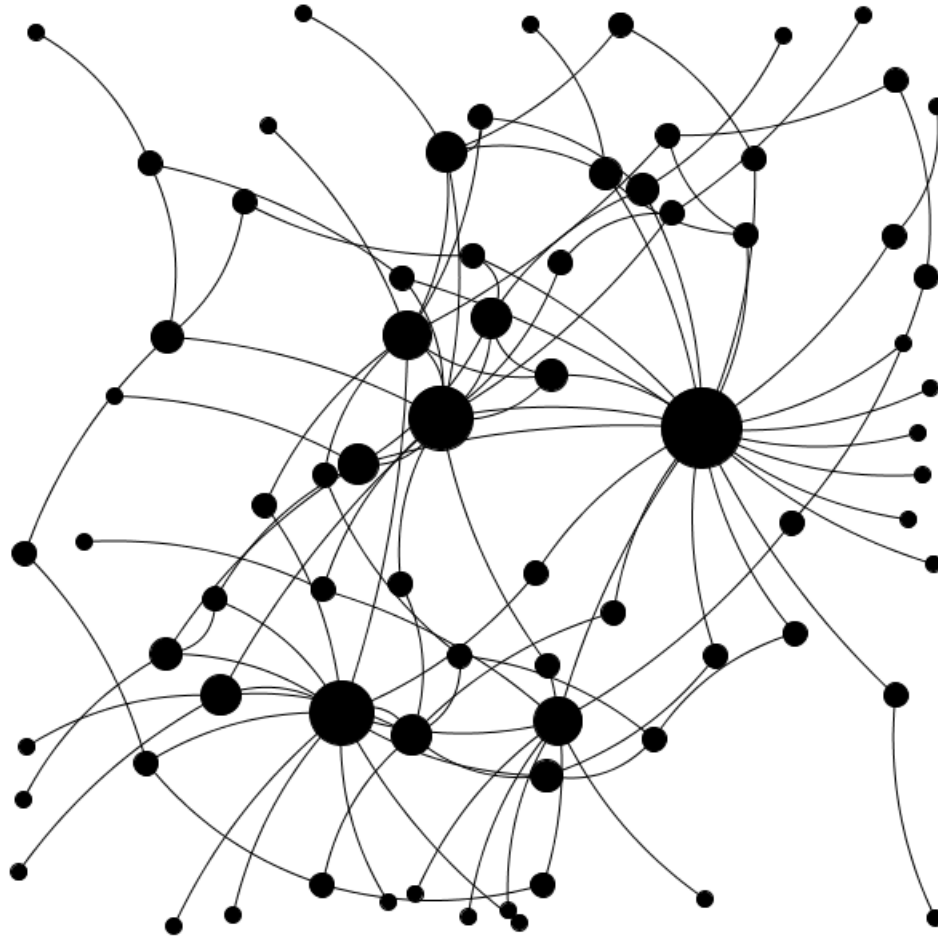
Many real world networks have a similar architecture:

Scale-free networks

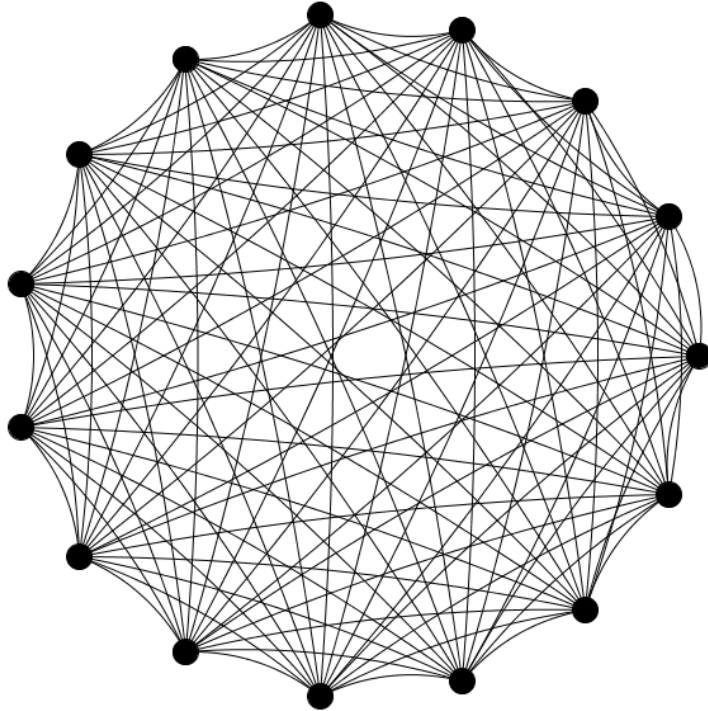
WWW, Internet (routers and domains), electronic circuits, computer software, movie actors, coauthorship networks, sexual web, instant messaging, email web, citations, phone calls, metabolic, protein interaction, protein domains, brain function web, linguistic networks, comic book characters, international trade, bank system, encryption trust net, energy landscapes, earthquakes, astrophysical network...

This slide has taken from Barabasi's *The architecture of complexity: From the topology of the www to the cell's genetic network*

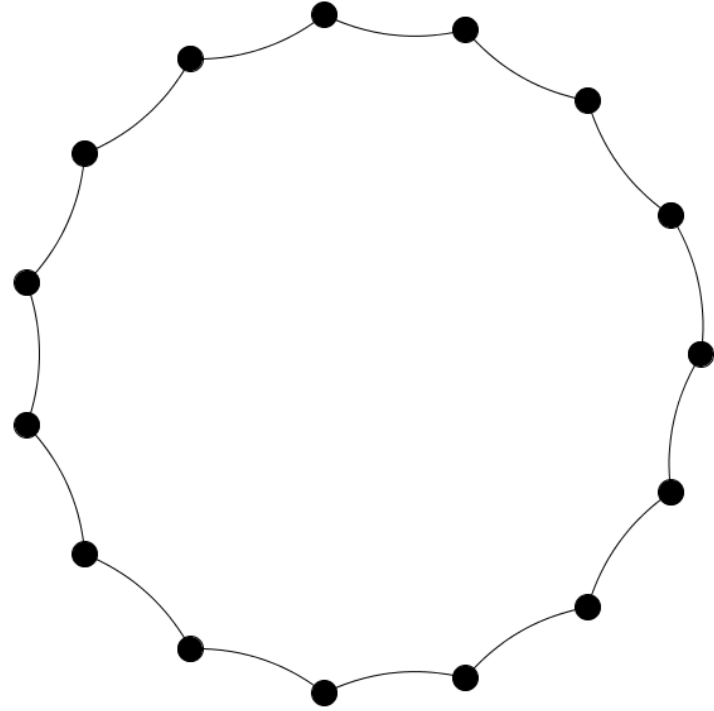
Topology: Scale Free



Topology: One Dimensional Lattices

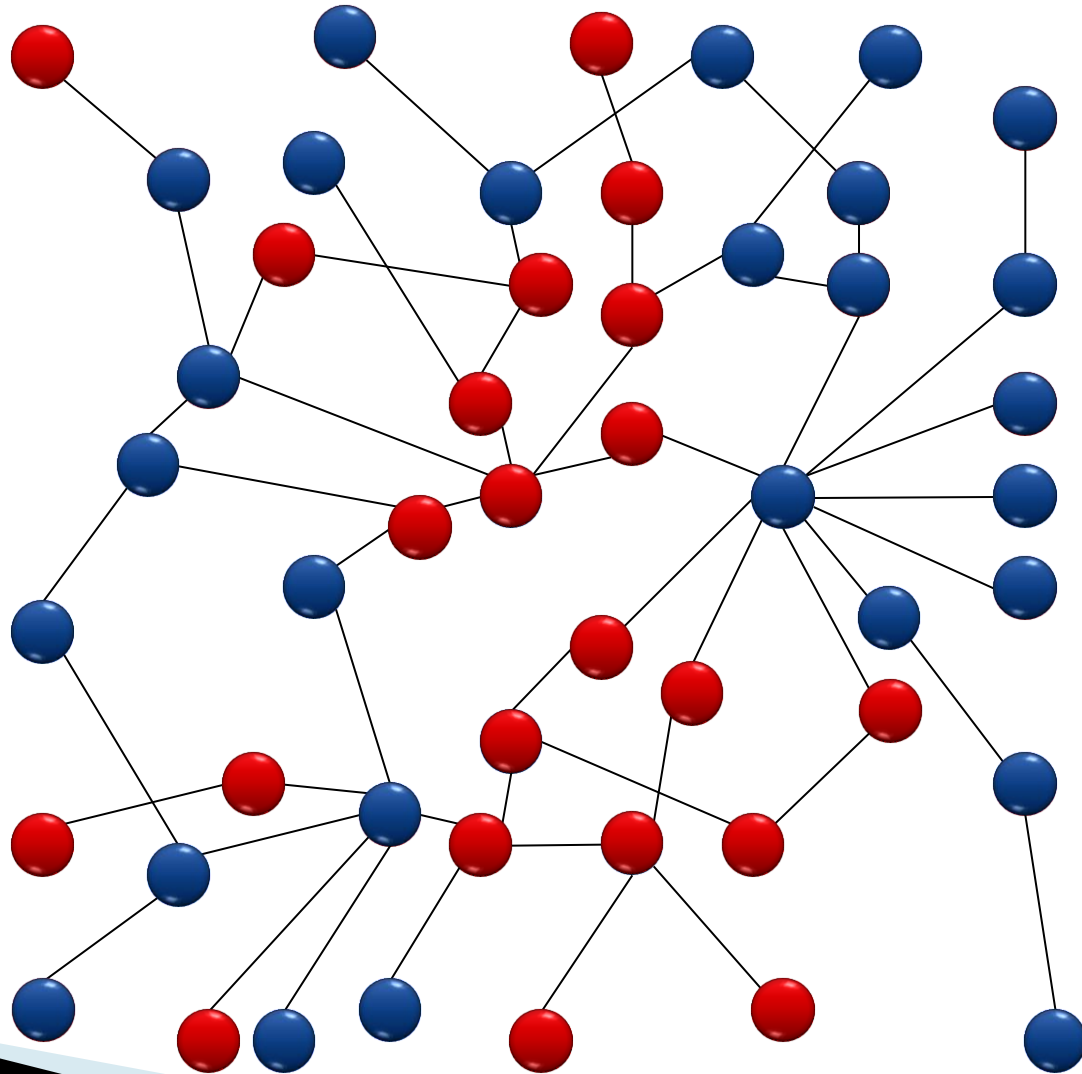


Fully Connected Network



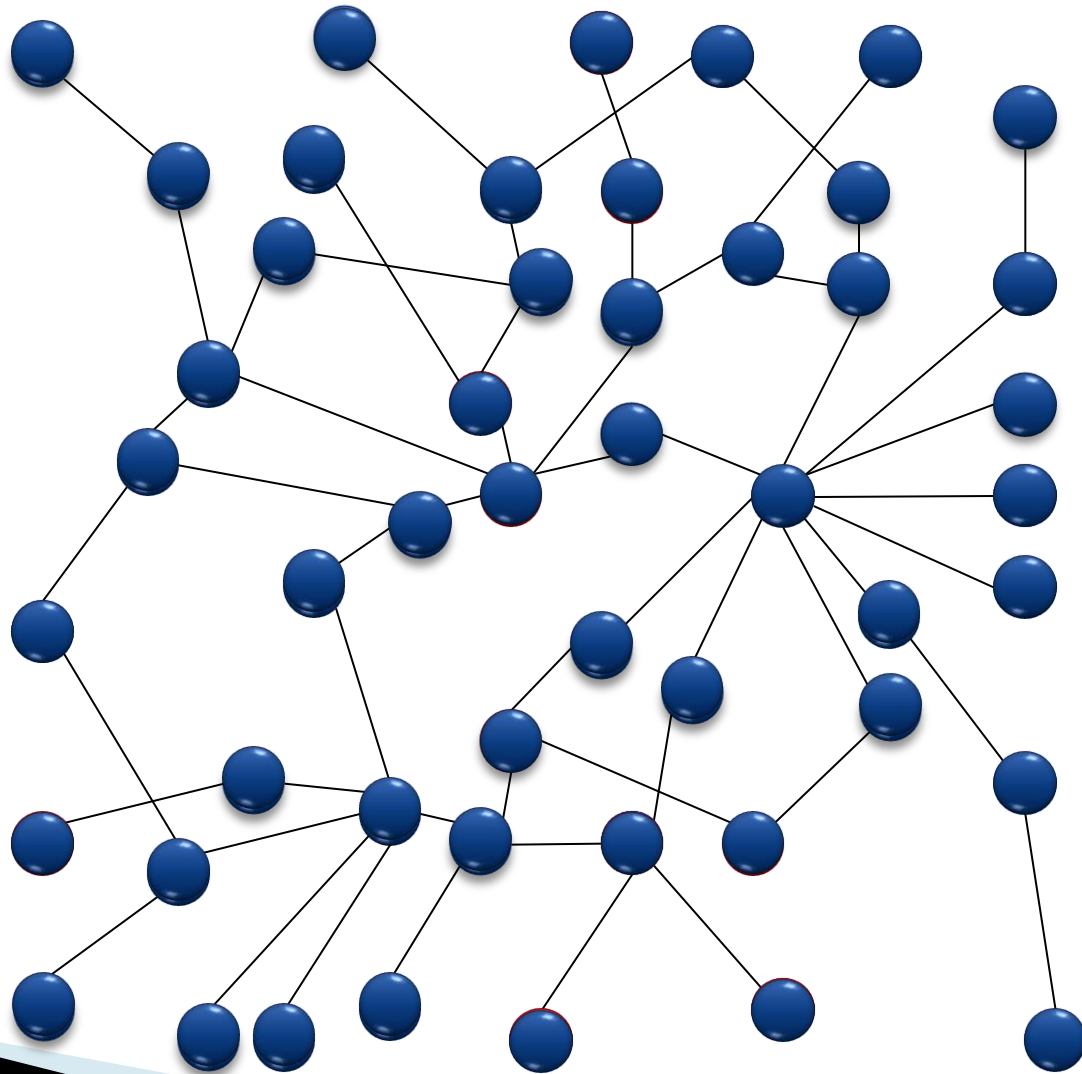
Ring Network

Convention Emergence (3)



Convergence = ~~54%~~ 64%

Convention Emergence (3)



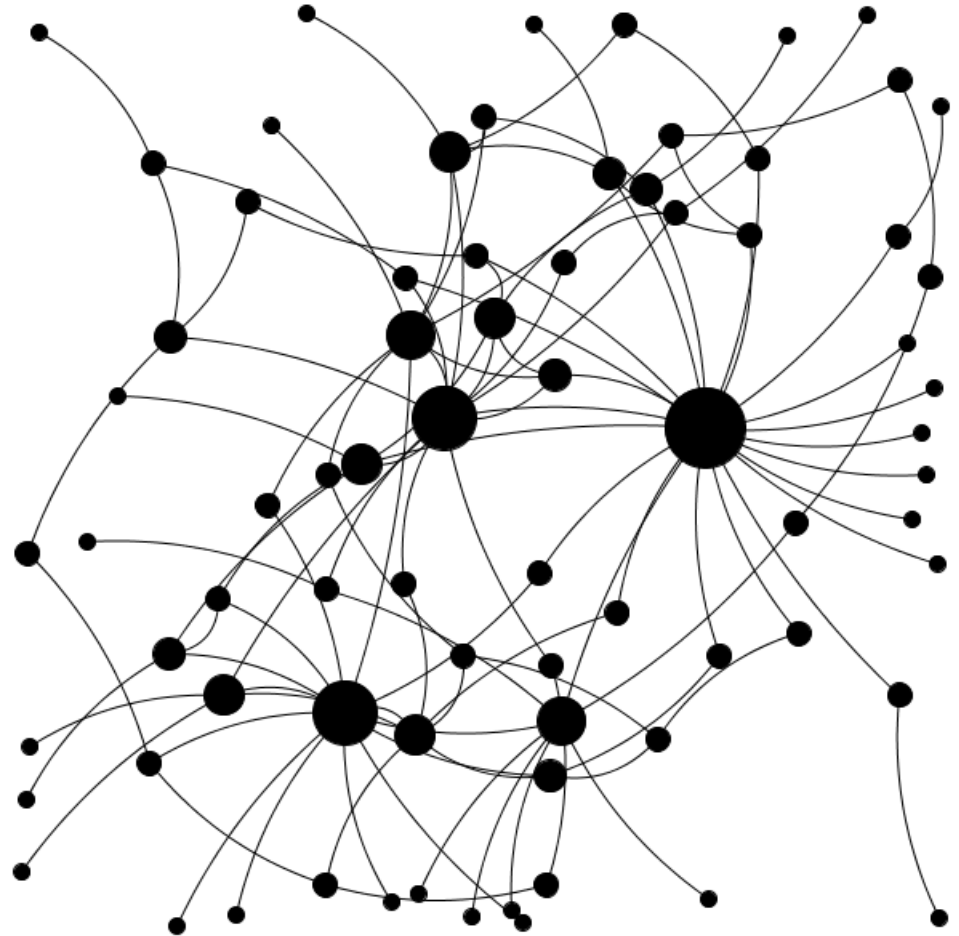
Convergence = ~~100%~~ 100%

Previous Work

Work	Game	Strategy Update	Instruments	Topology	Convergence
[Shoham and Tennenholtz, 1994]	CG & PD	HCR	Memory Restarts	NT	85%
[Kittock, 1993]	CG & PD	HCR	None	RN	90%
[Kittock, 1994]	CG	HCR	Authority	G & T	100%
[Shoham and Tennenholtz, 1997b]	CG & PD	HCR	Memory Restarts	NT	95%
[Young, 1993]	SD	Selective Majority	None	NT	Theoretical
[Sen and Airiau, 2007]	CG & SD	Q-Learning, FP & WoLF-PHC	None	NT	90%
[Mukherjee et al., 2008]	CG	Q-Learning, FP, WoLF-PHC & HCR	None	G	Avg Payoff 3.5
[Delgado, 2002]	CG	Generalized Simple Majority & HCR	None	SF-AB	90%
[Delgado et al., 2003]	CG	Generalized Simple Majority & HCR	None	SF-AB, SF-W & SF-F	90%
[Pujol et al., 2005]	CG	HCR	<i>Imitation</i>	Rand, RN, SW & SF-AB	95%
[Urbano et al., 2009a]	CG	Recruitment based on Force with Reinforcement	<i>Force</i>	Rand, RN, SW & SF-AB	90%
[Urbano et al., 2009b]	CG	External Majority	<i>Memory</i>	Rand, RN, SW & SF-AB	90%
[Walker A, 1995]	CG	7 implementations of <i>Majority Rules</i>	None	G	100%
[Savarimuthu et al., 2007b]	UG	Unspecified	None	DN	100%
[Mungovan et al., 2011]	CG	Weighted Replicators Dynamic	Random Interactions	SW + Rand	100%

Scale Free Networks

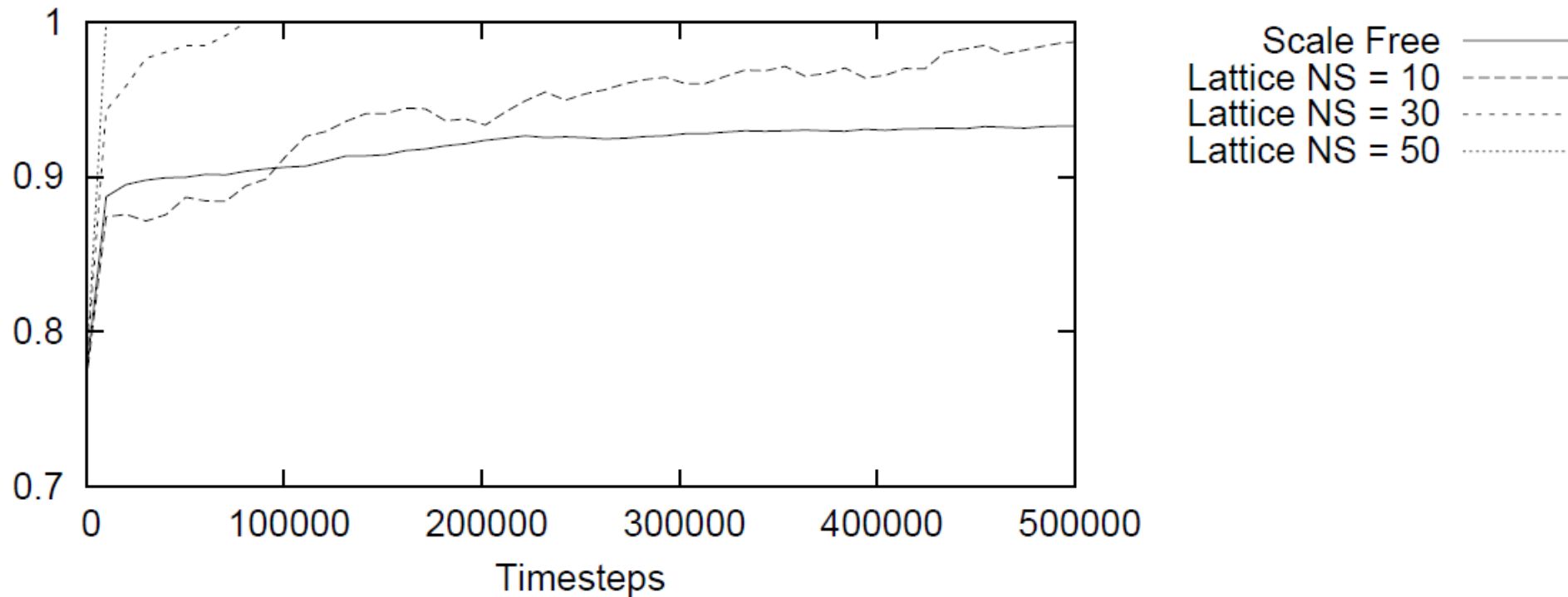
- ▶ Reaching 90% of convergence is FAST. [Delgado, Puyol, Sangüesa; Kittock]
- ▶ But what happen with the other 10%?



Experimental Setting

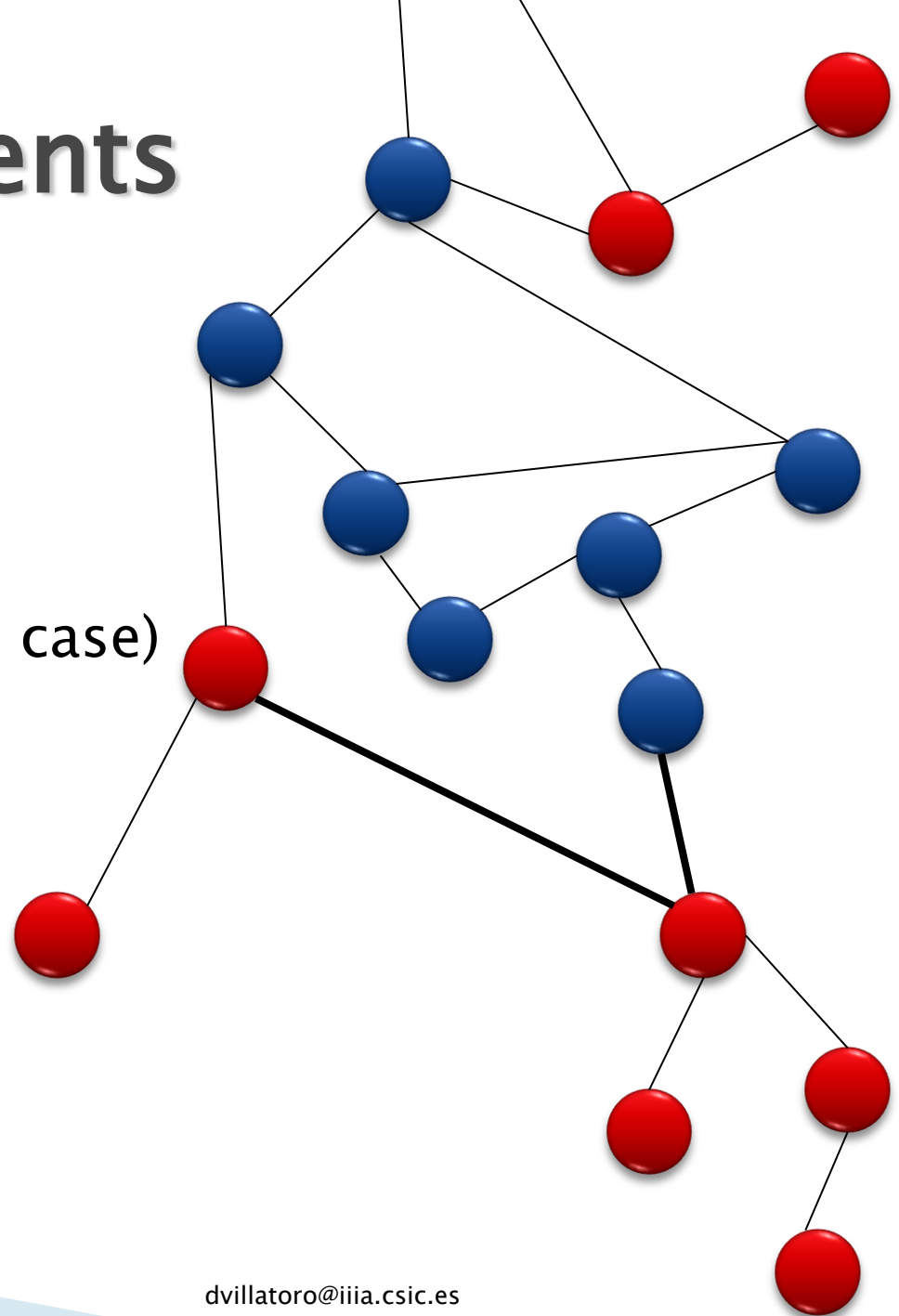
- ▶ 100 Agents on Different **Networks**.
- ▶ Every agent interacts with **randomly chosen neighbor**.
- ▶ Agents choose action following **Reinforcement Learning** (RL) Algorithms:
 - Q-Learning: 75% exploitation and 25% exploration.
- ▶ Once both players choose their action, reward assigned and update their RL.
- ▶ **Convergence at 100%**
 - All agents choosing the same strategy/action/color.

First Result



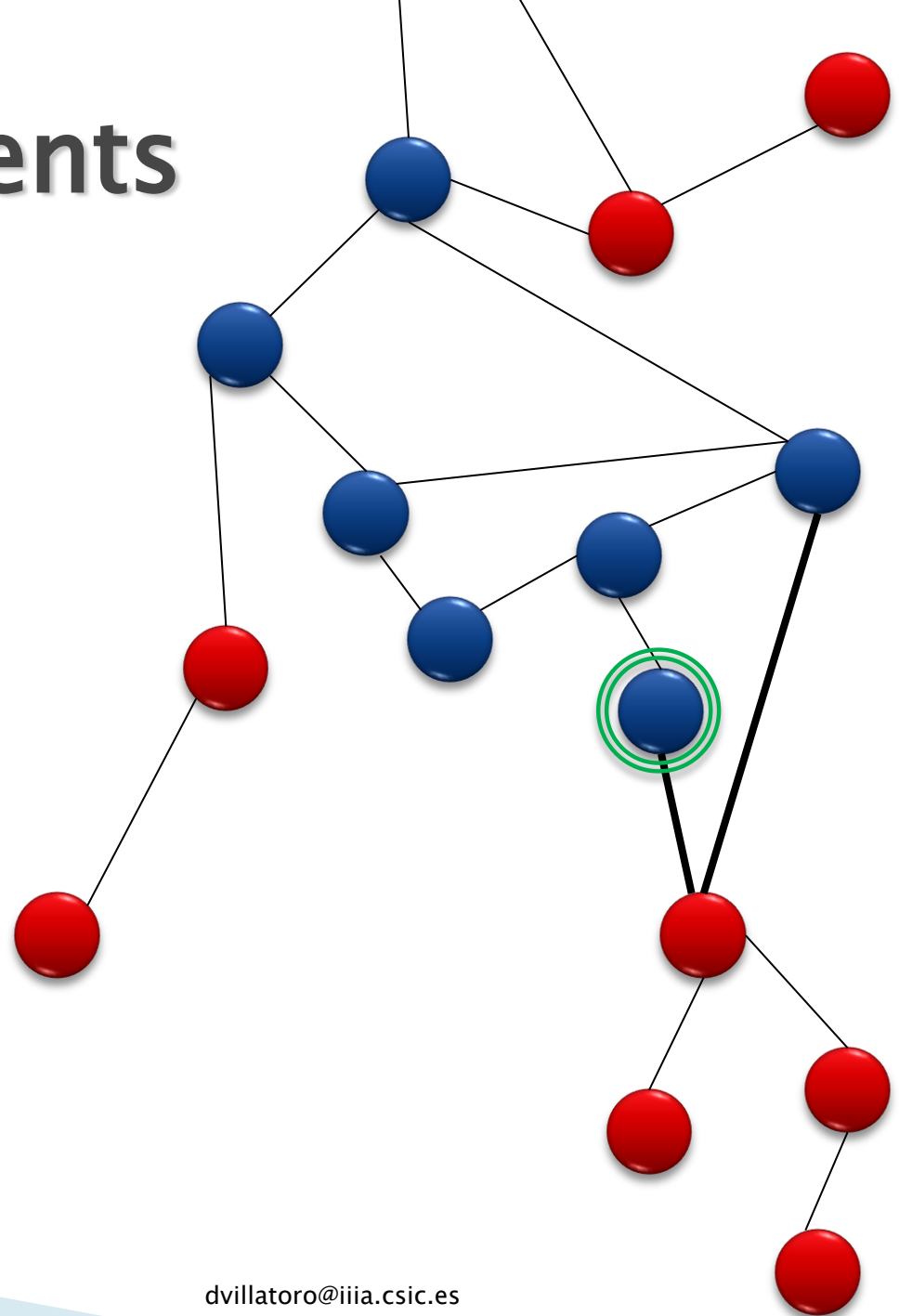
Social Instruments

- ▶ Rewiring
 - Random Rewiring
 - Neighbour's Advice
 - Global Advice (control case)



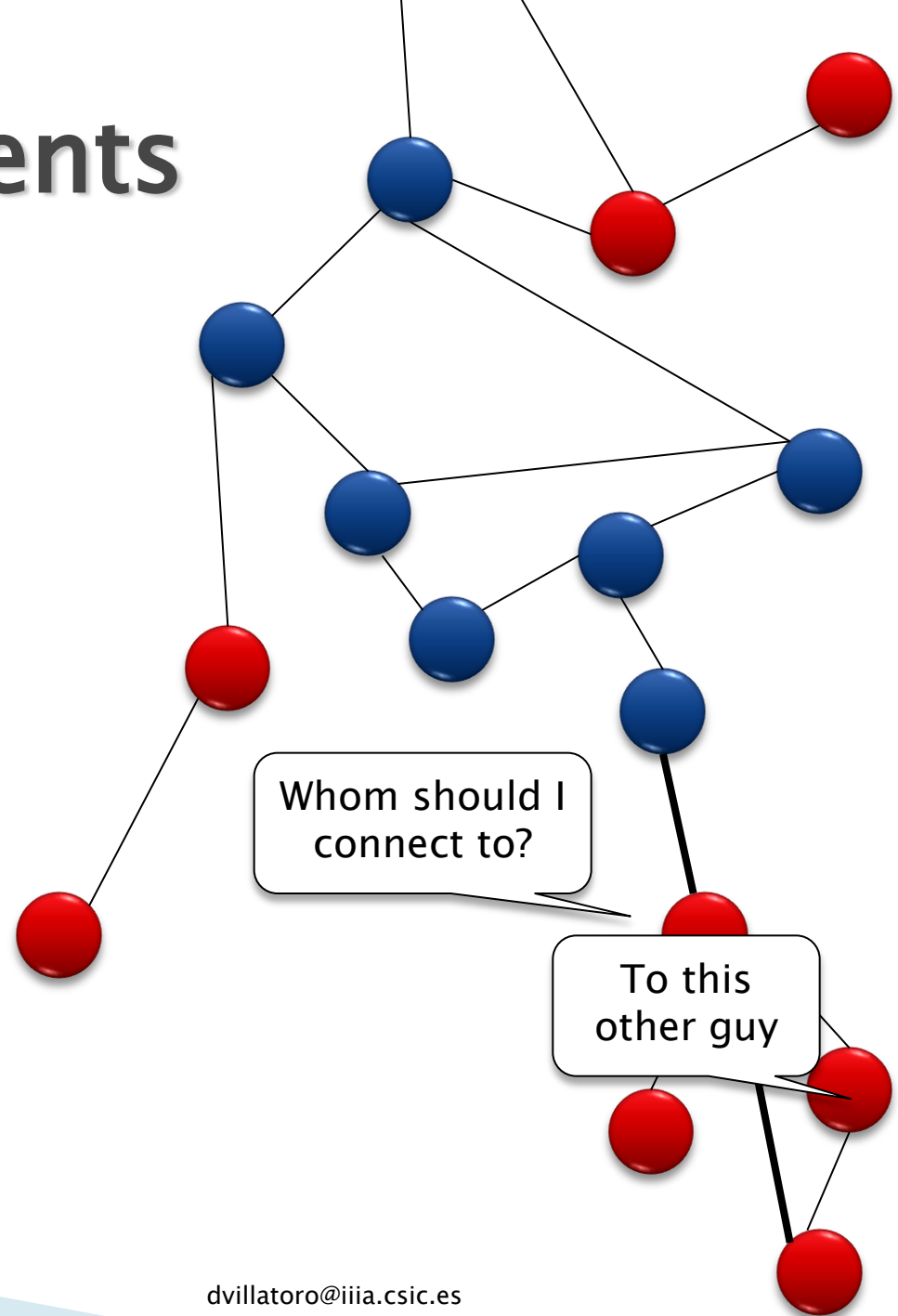
Social Instruments

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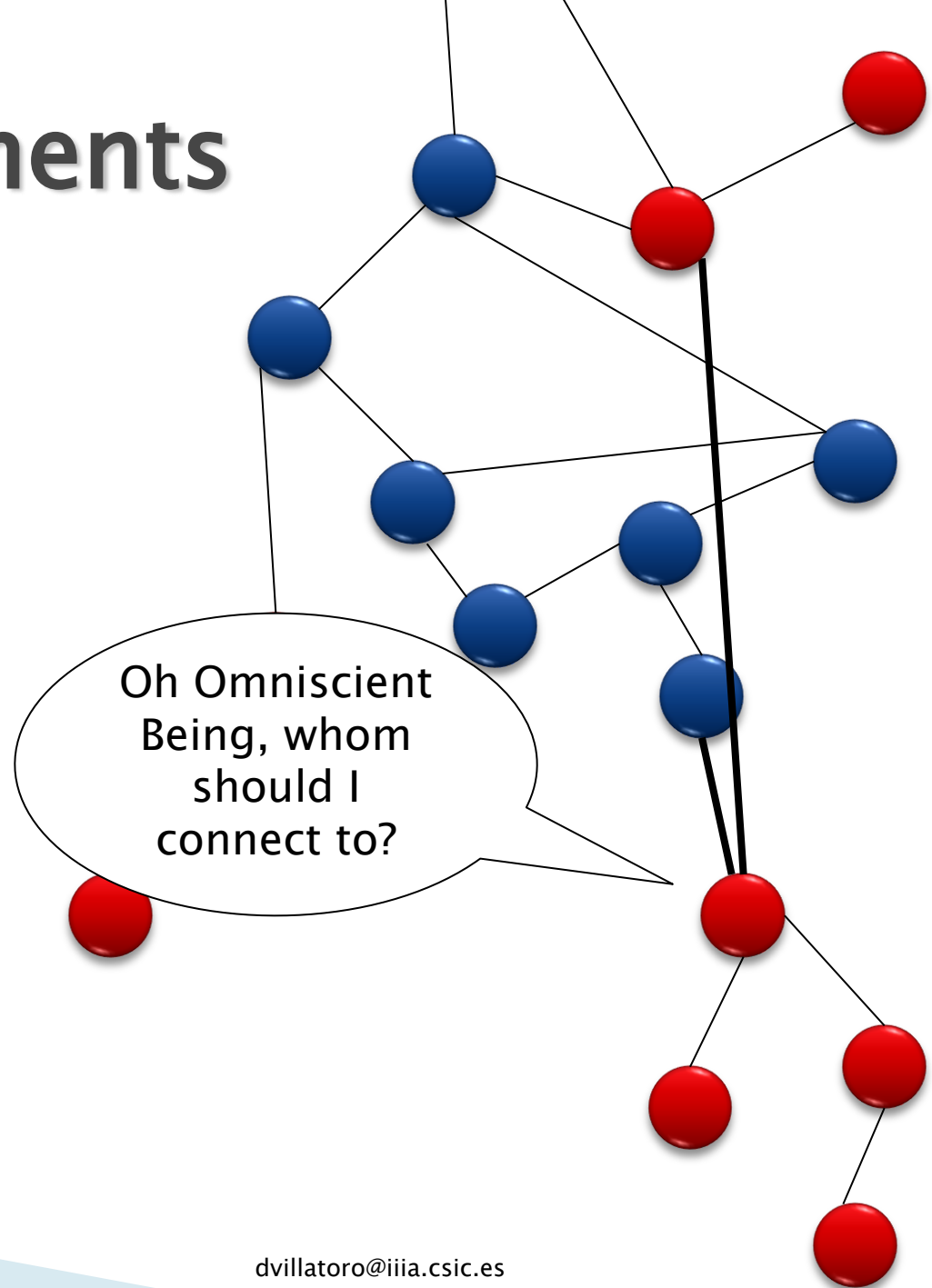
Social Instruments

- ▶ Rewiring
 - Random Rewiring
 - **Neighbour's Advice**
 - Global Advice



Social Instruments

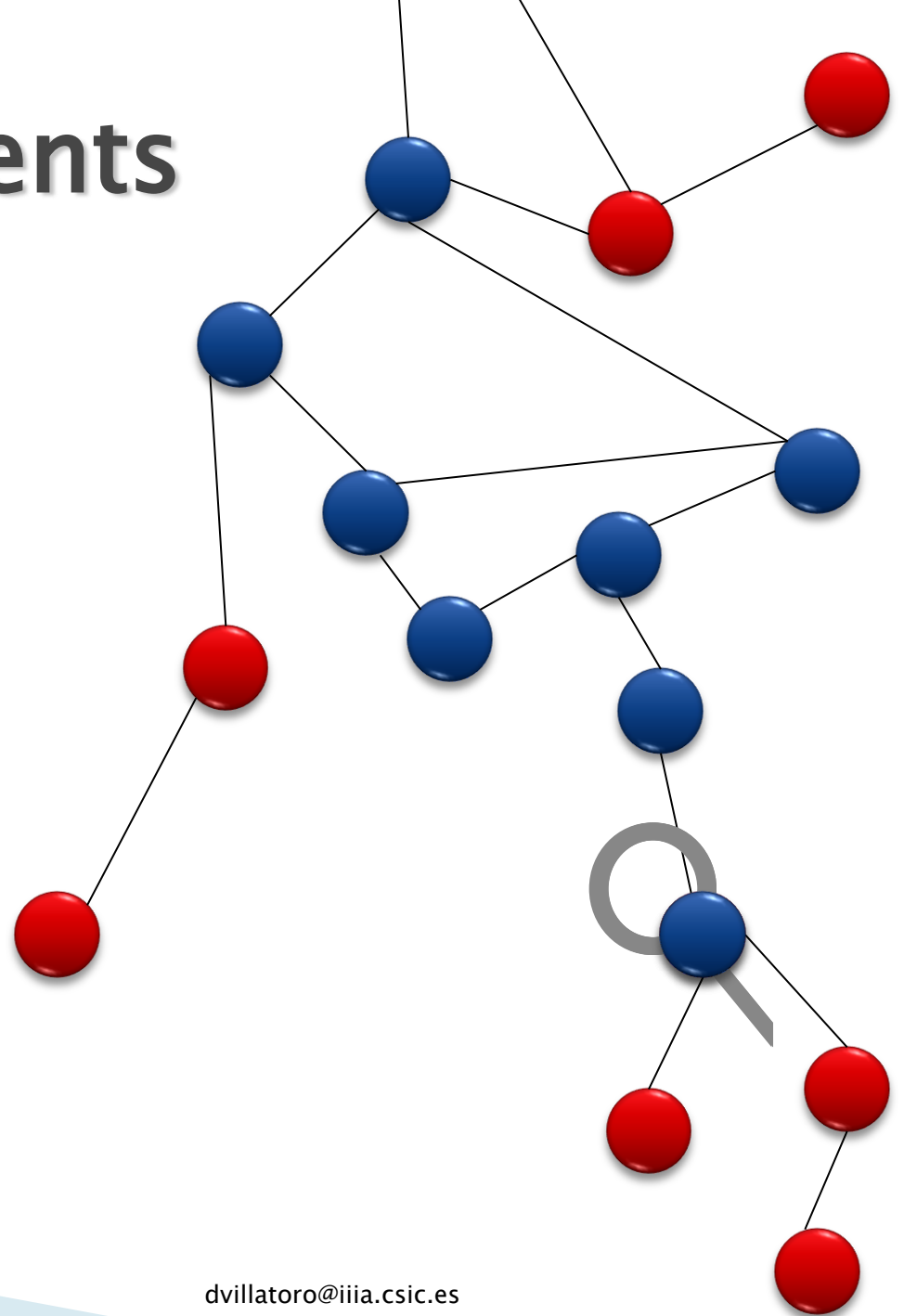
- ▶ Rewiring
 - Random Rewiring
 - Neighbour's Advice
 - **Global Advice**



Social Instruments

► Observation

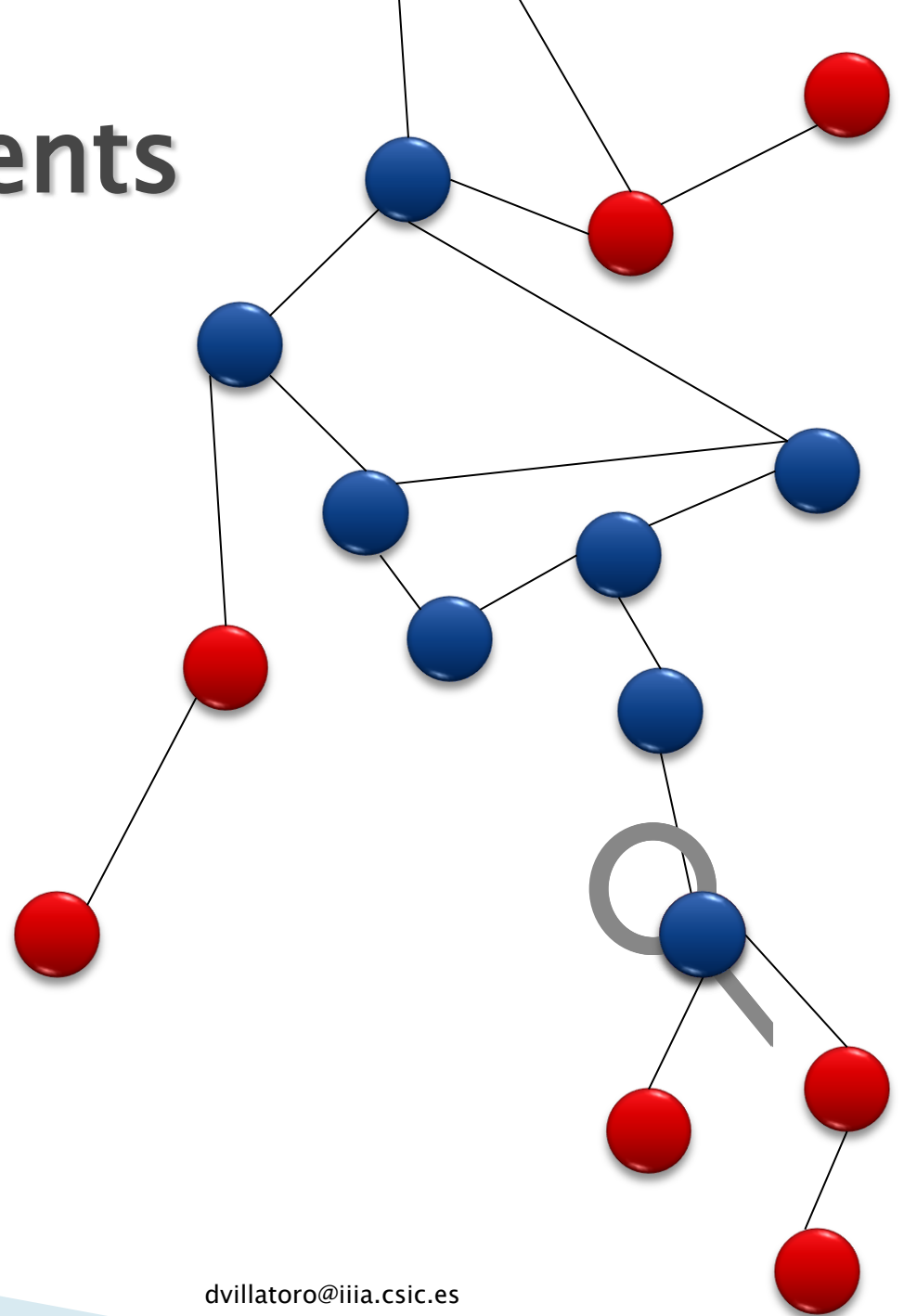
- Random
- Local
- Focal



Social Instruments

► Observation

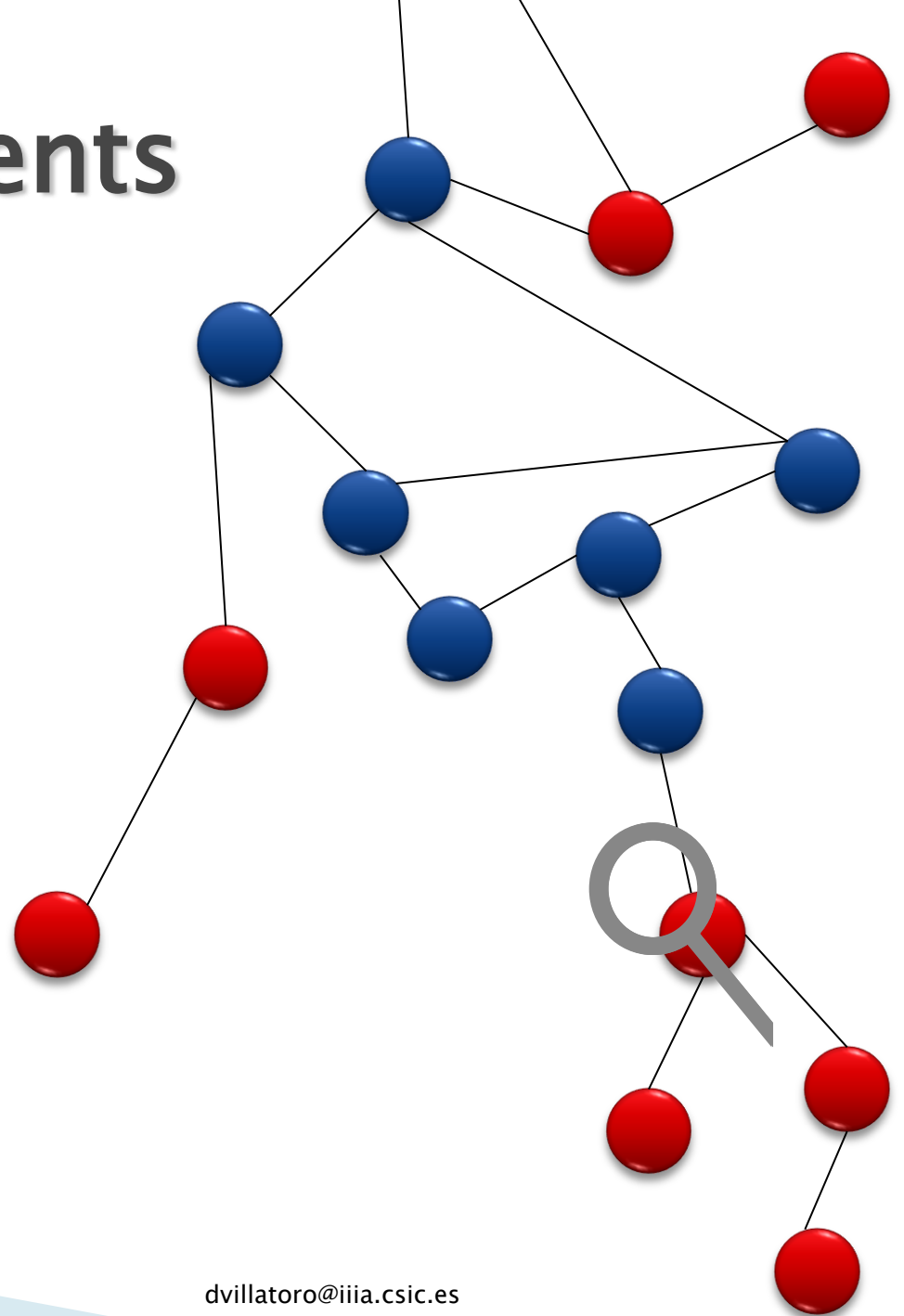
- **Random**
- Local
- Focal



Social Instruments

► Observation

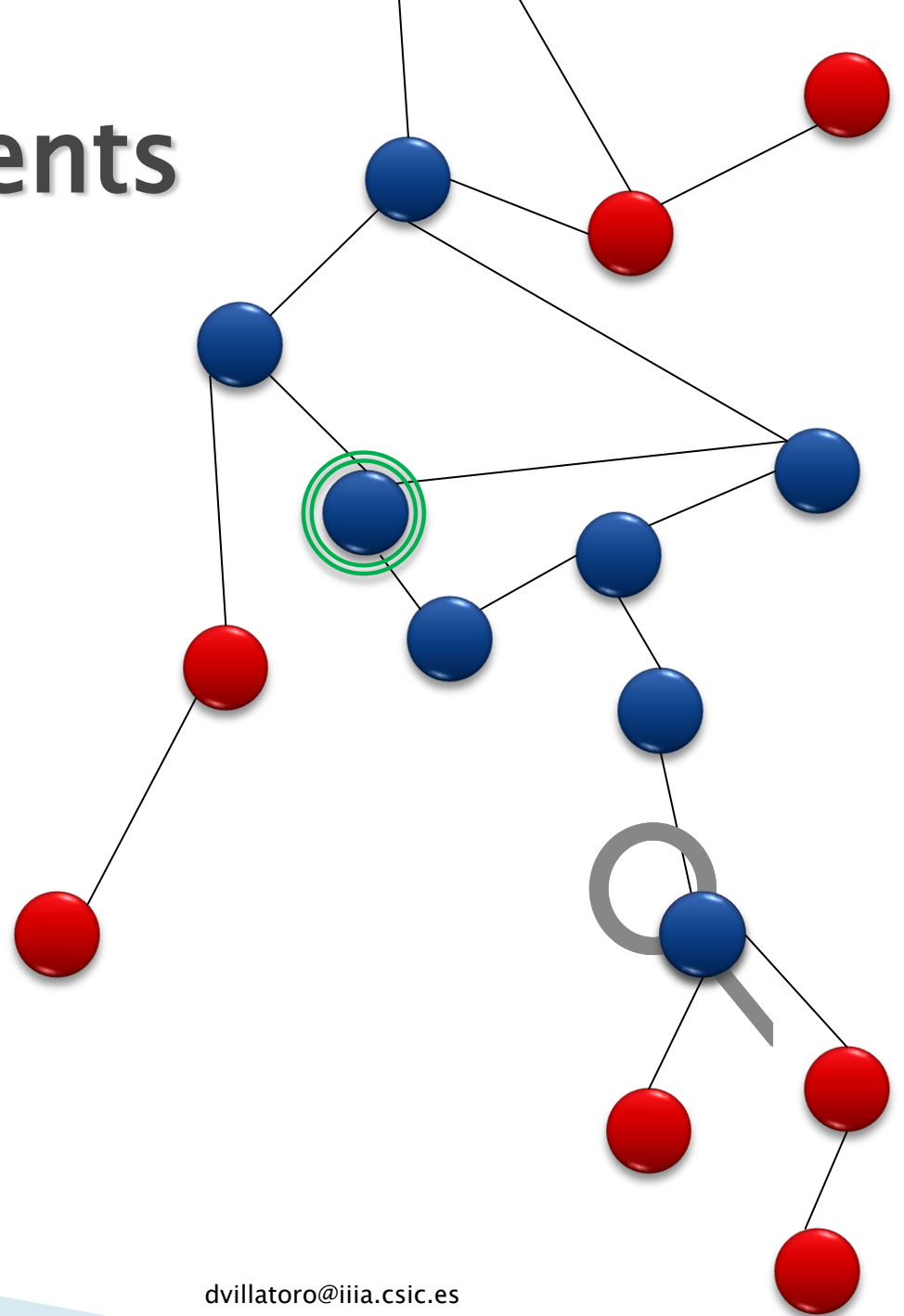
- Random
- **Local**
- Focal



Social Instruments

► Observation

- Random
- Local
- **Focal**



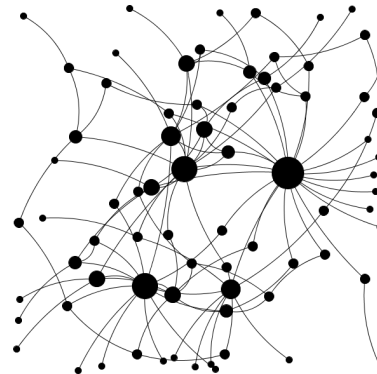
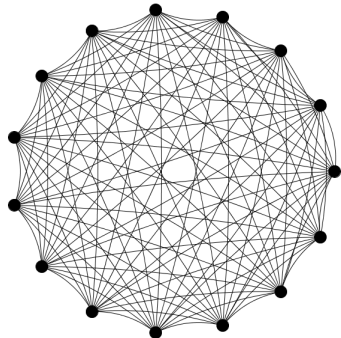
Exploring the Search Space

- ▶ Population Size.
 - 100 up to 1000.
- ▶ Underlying Topology.
 - Lattices and Scale-Free..
- ▶ Learning Algorithms.
 - Q-Learning, WoLF, Fictitious Play, HCR.
- ▶ Strategy Selection Rules:
 - BRR, HCRR, MBR.

Results on Rewiring

► Topology:

- Low clustered societies perform better with rewiring.

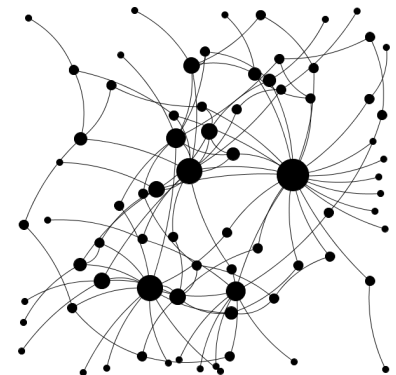
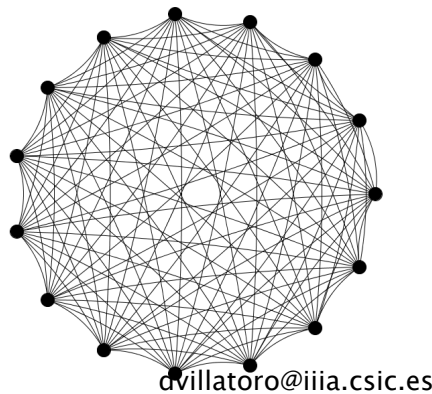


► Rewiring Methods:

- Global Advice performs best.
- **Neighbour's Advice** creates clustered societies, but performs better than Random.

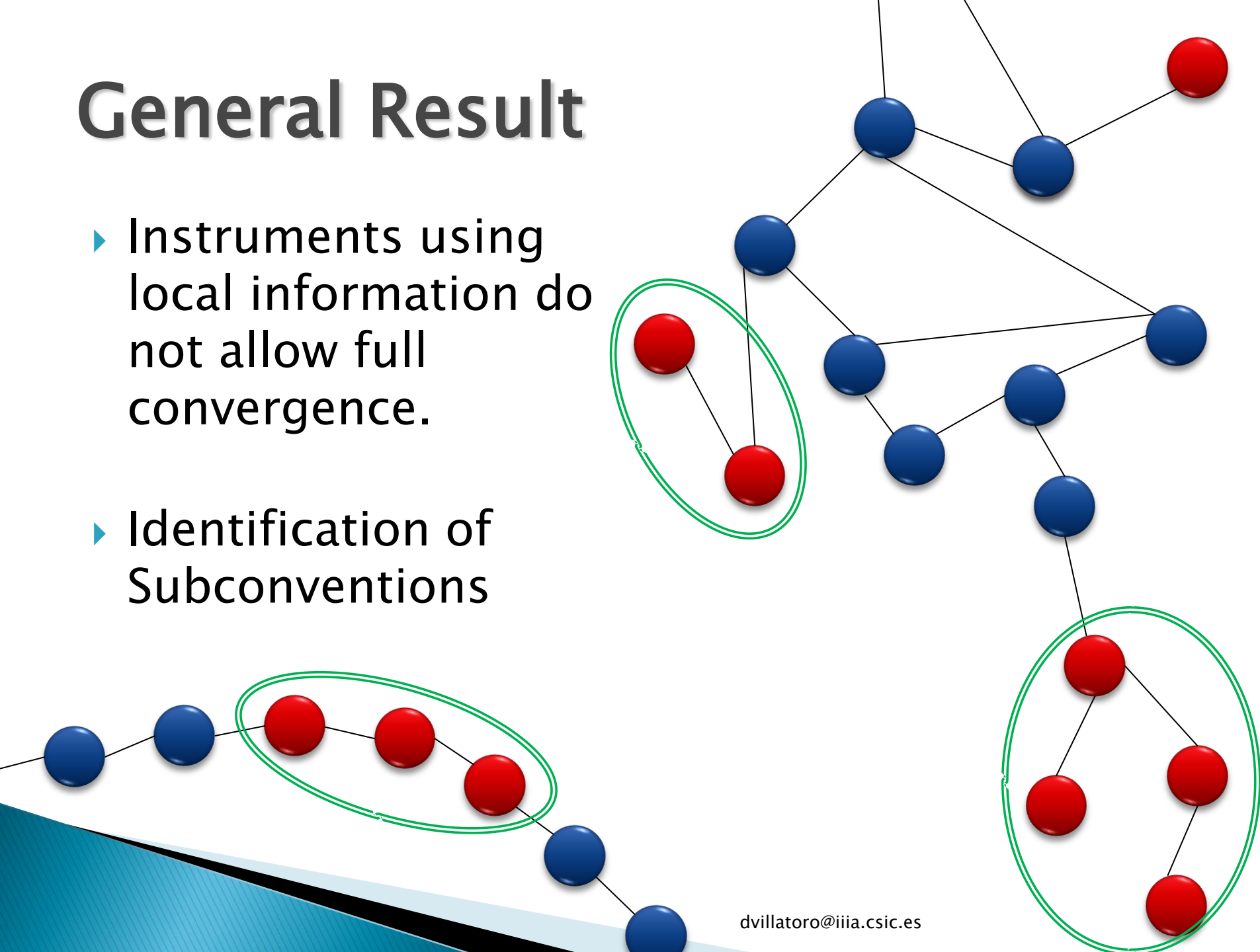
Results on Observation

- ▶ Observation Methods:
 - **Local observation delays** the emergence of global conventions.
 - Reinforcement of **Subconventions**.
- ▶ Topology:
 - All methods perform better in societies with high diameter.
 - Otherwise, agents can “access” information from the whole network.

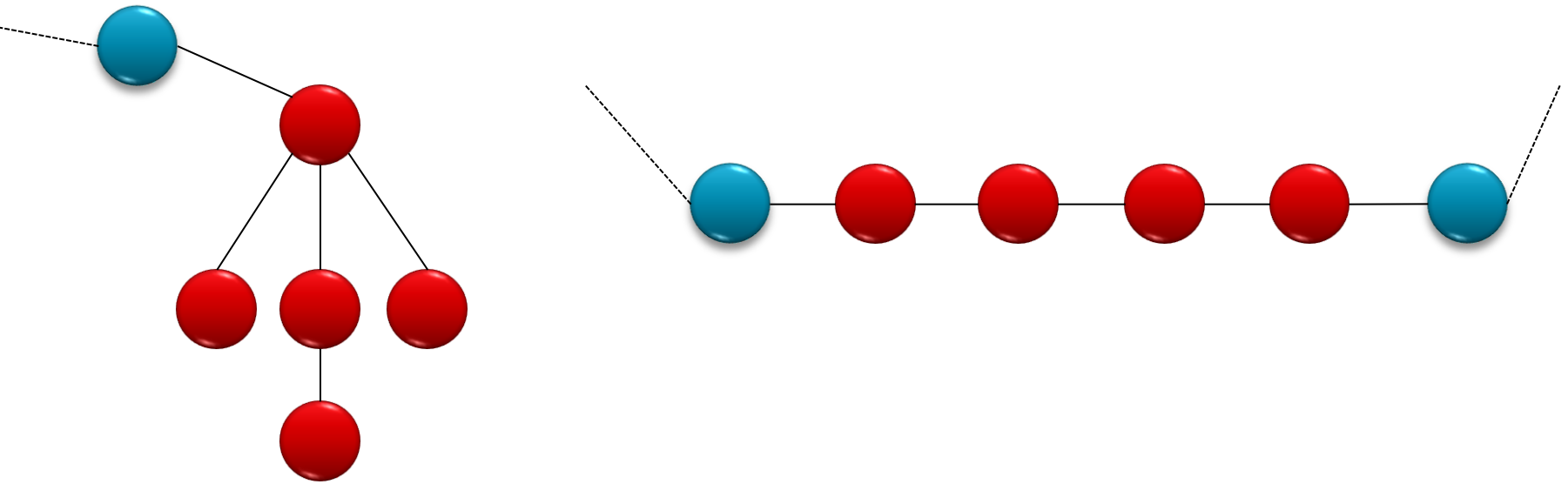


General Result

- ▶ Instruments using local information do not allow full convergence.
- ▶ Identification of Subconventions



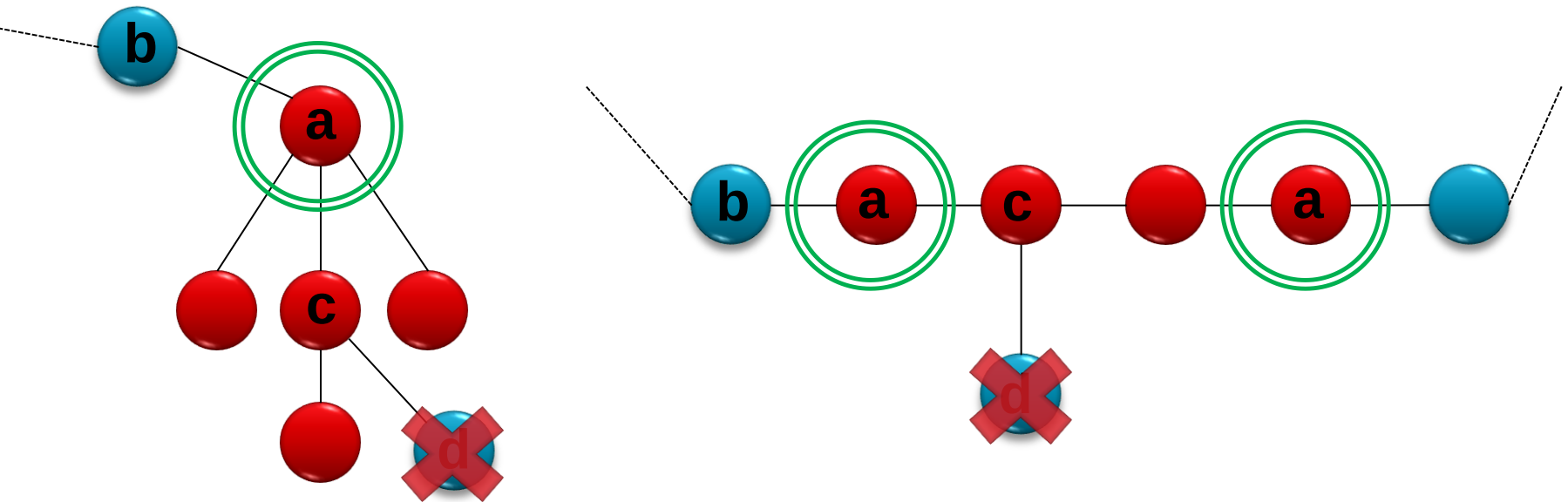
Subconventions



► $\text{Sub}^t \subset A$ where:

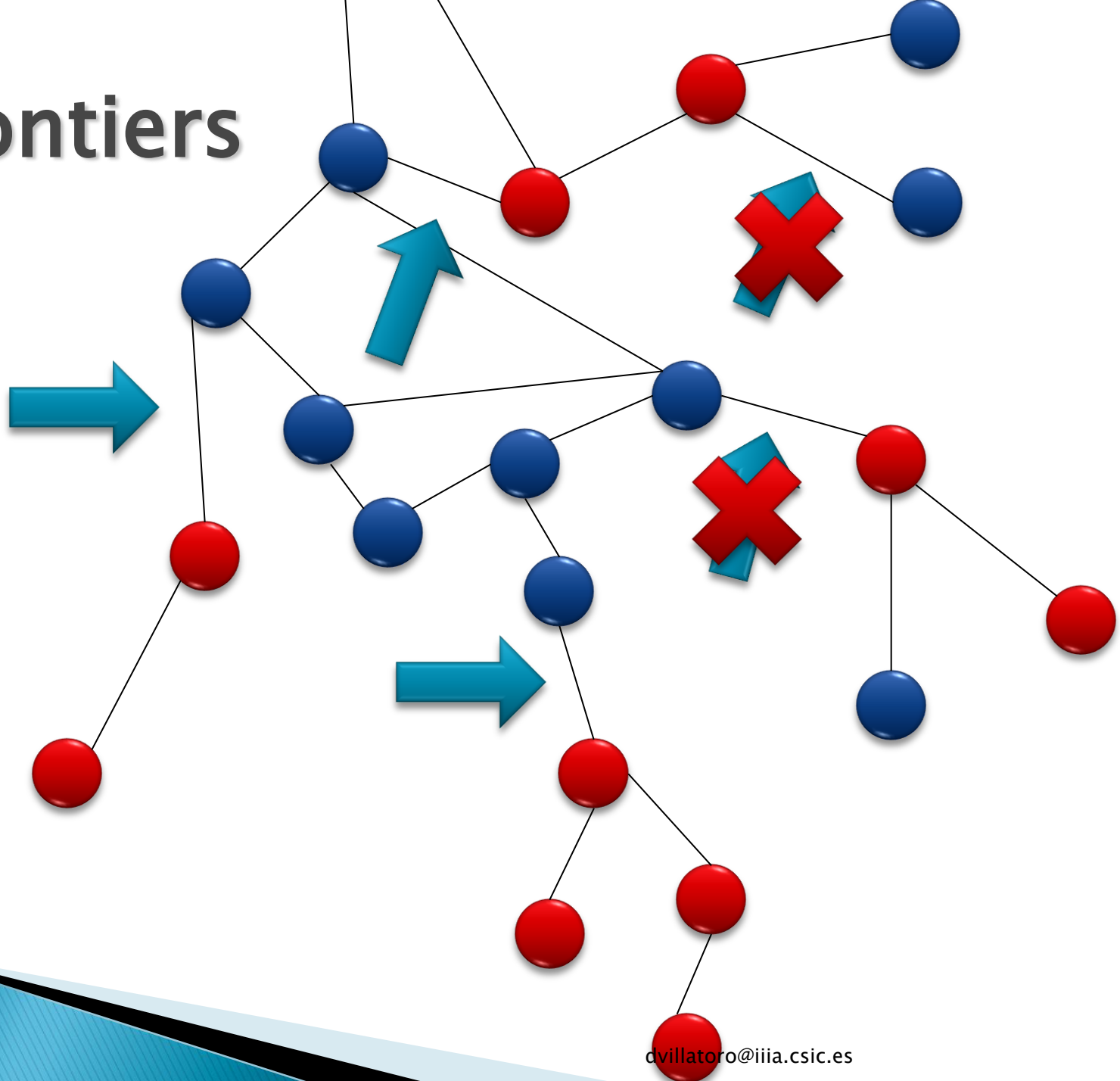
- $\forall a \in \text{Sub}^t, \exists b \in \text{Sub}^t \mid \text{Rel}^t(a,b) \wedge S_a^t == S_b^t \wedge$
- $\exists i,j,k \in \text{Sub}^t \text{ Rel}(i,j) \wedge \text{Rel}(j,k) \wedge \neg \text{Rel}(i,k) \wedge S_i^t == S_j^t == S_k^t$

Frontier

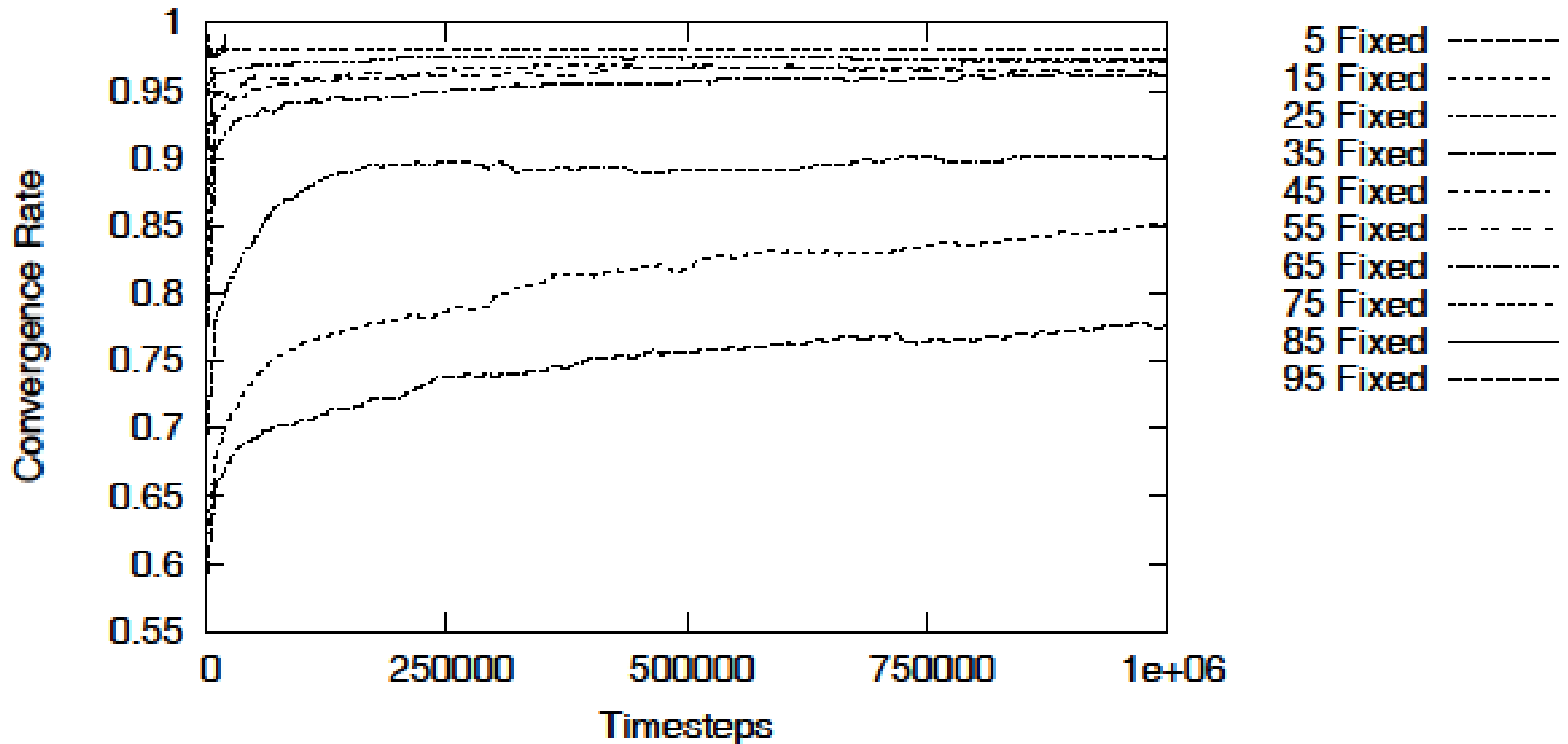


- $a \in \text{Sub}^t \wedge \exists b \notin \text{Sub}^t \wedge \text{Rel}(a,b) \wedge S_a^t \neq S_b^t \wedge$
 $(\exists c \in \text{Sub}^t \wedge \text{Rel}(a,c) \nexists d \in A \mid \text{Rel}(c,d) \wedge S_c^t \neq S_d^t)$

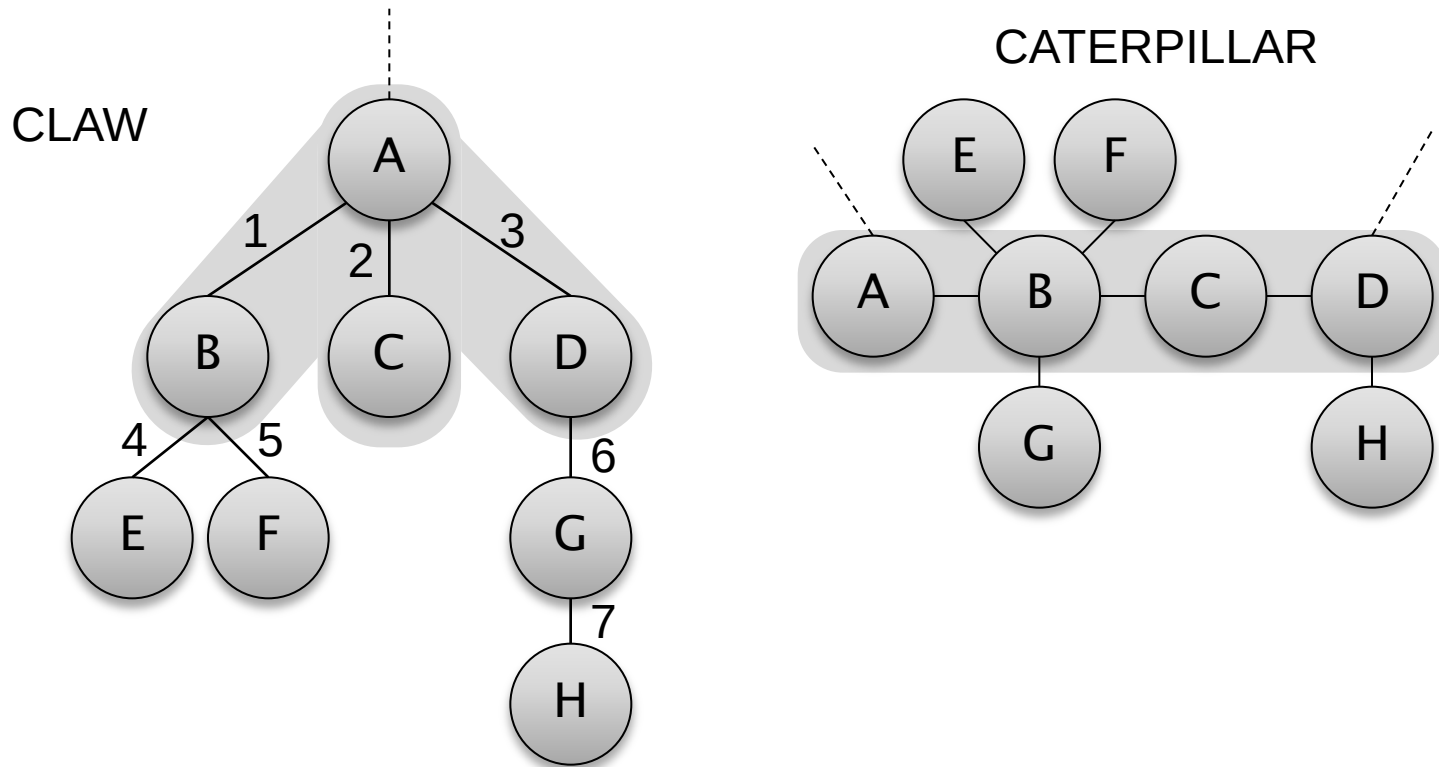
Frontiers



Analyzing Scale Free



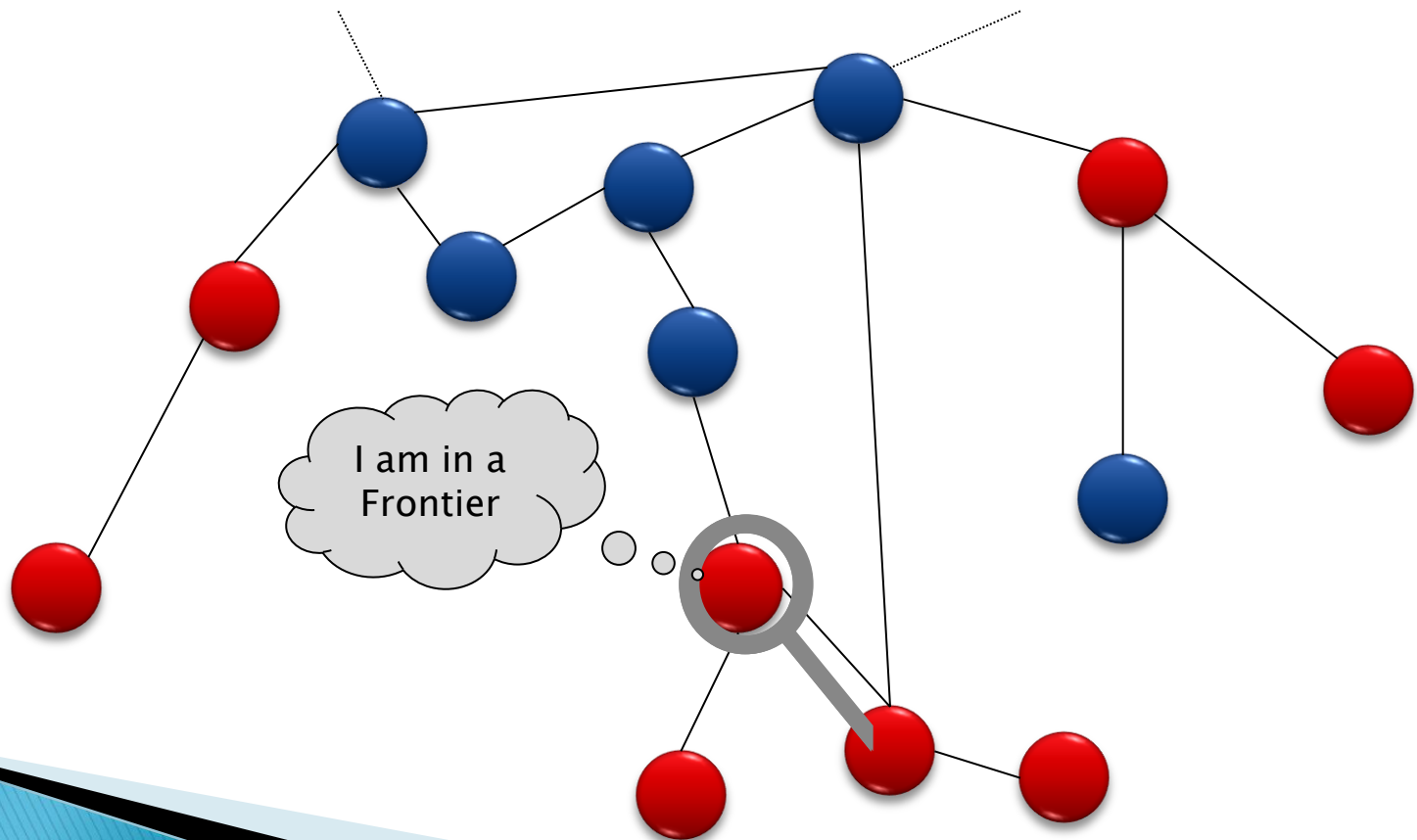
Self-Reinforcing Structures



- ▶ 74% of the Scale Free Networks* contain SRS.
 - Generated with 3 different algorithms and State of the Art Parameters

Dissolving SRSs

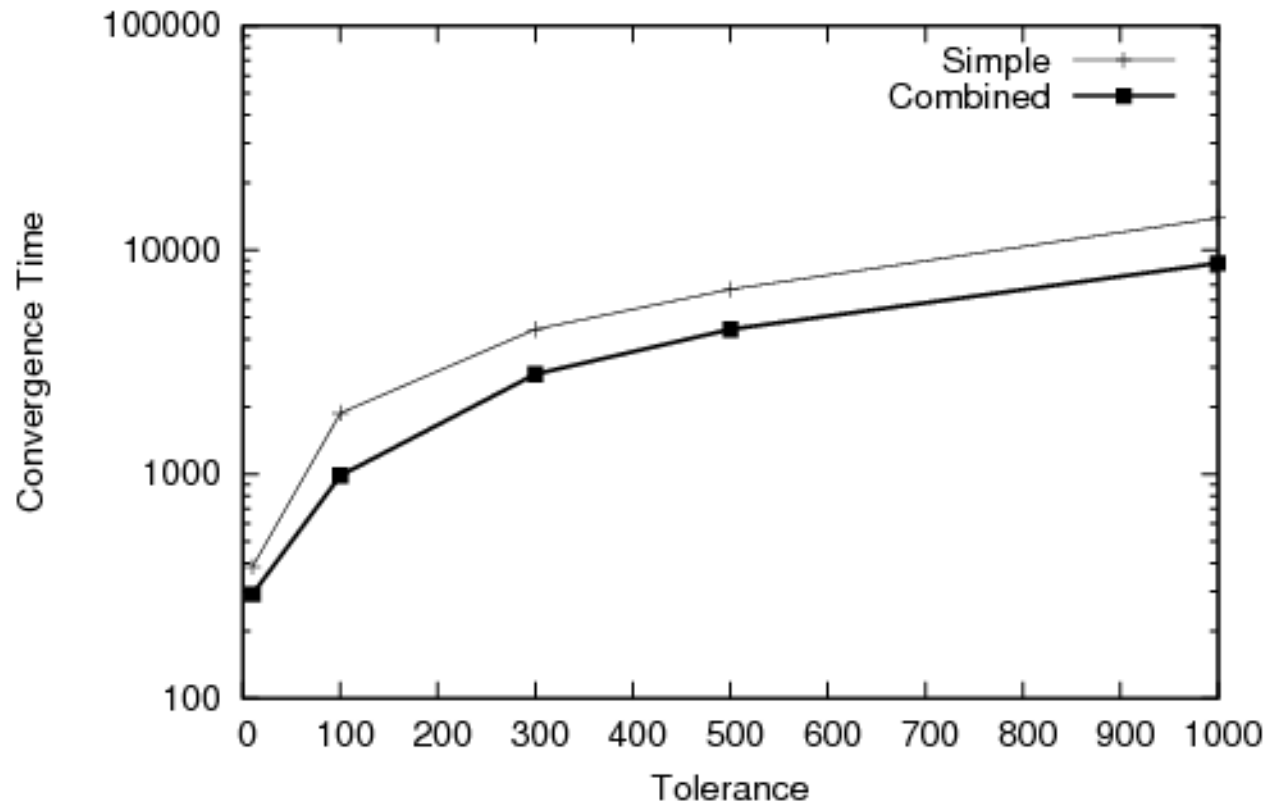
- ▶ Using Observation to identify SRSs
- ▶ Apply Rewiring to dissolve SRSs.



Results on SRS

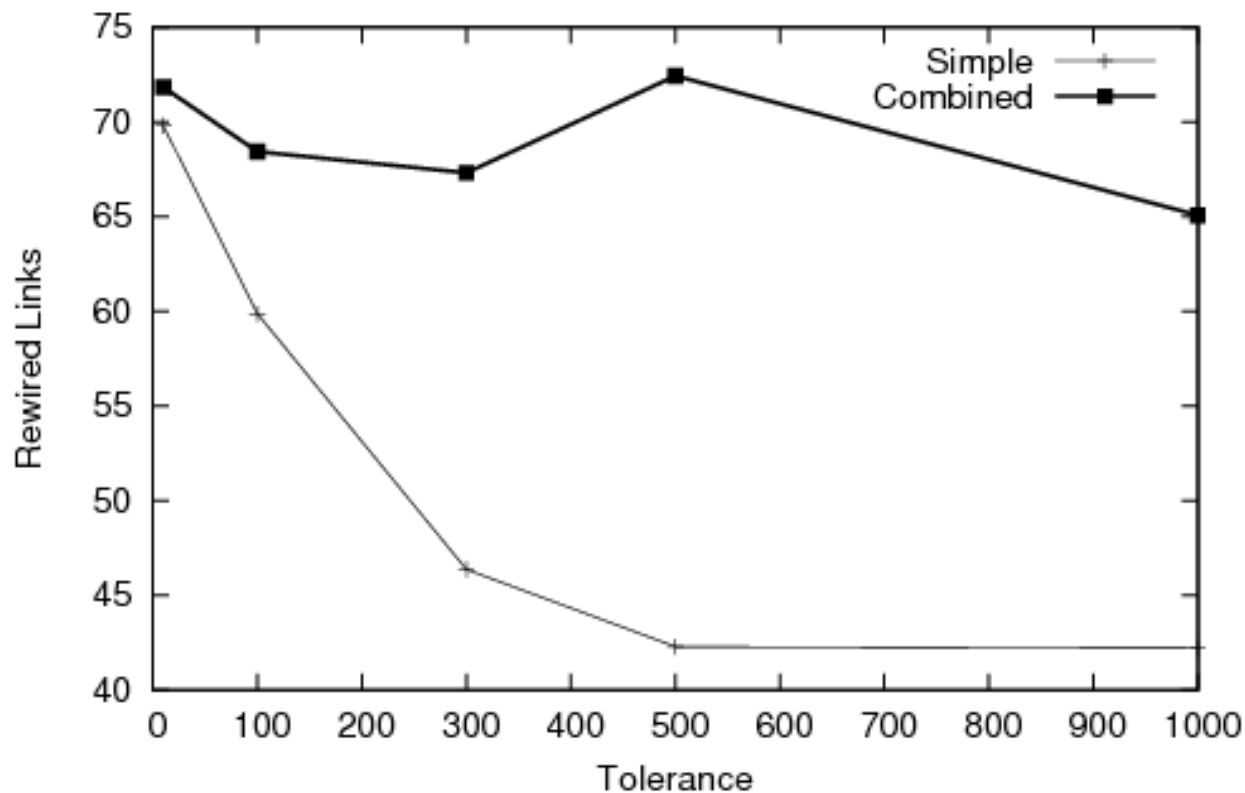


- ▶ Reduced Convergence Time.



Results on SRS (2)

- Increased the number of Rewired Links.



Conclusions on Convention Emergence

- ▶ Simple dynamic – Hard Problem on complex networks.
- ▶ Identification of Self-Reinforcing Structures.
 - Dissolution with Social Instruments.
- ▶ Full convergence possible.

Future Work

- ▶ SRS Dissolution maintaining Scale-Free Structure.
- ▶ Explore the effect of Social Instruments on other games:
 - Prisoner's Dilemma

Thanks!

Questions?

Come and See the Poster
tomorrow 11:30–12.10 @ Rooms
122–123