London, April 11-12 2015

A visual analytics approach to compare propagation models in social networks

J. Vallet, H. Kirchner, B. Pinaud, G. Melançon

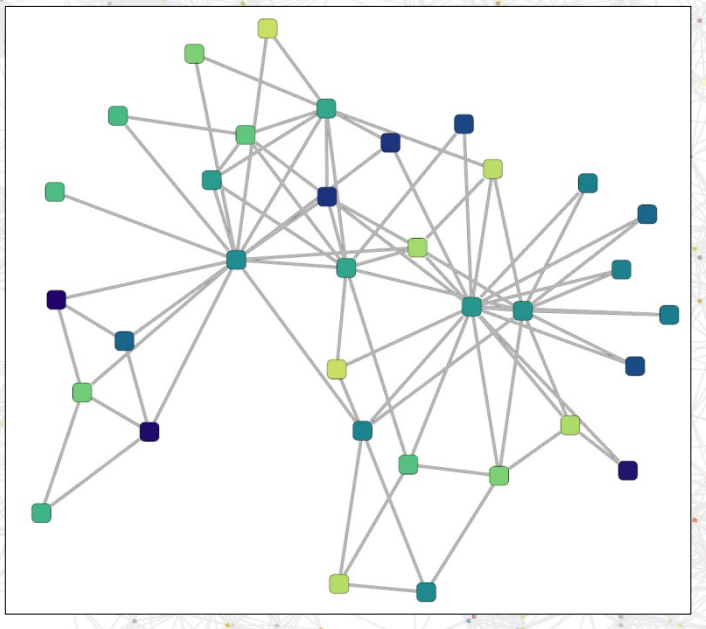
LaBRI, UMR 5800
Inria Bordeaux
Univ. Bordeaux

We want to...

- Study propagation models and social networks
- Compare the propagation models
- Use graph rewriting techniques to represent models and run propagation simulations
- Perform visual analysis

Definitions

A social network:



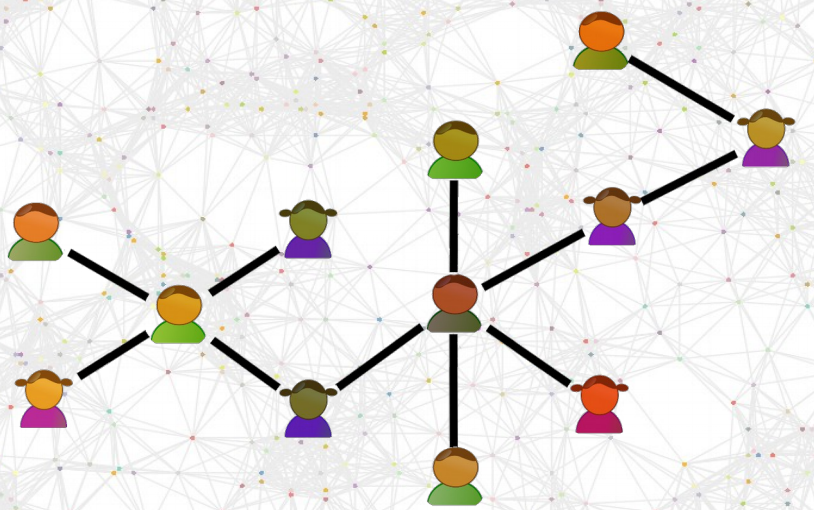
W. W. Zachary, An information flow model for conflict and fission in small groups, Journal of Anthropological Research 33, (1977).

Described as a graph $G=(V,E)$ with

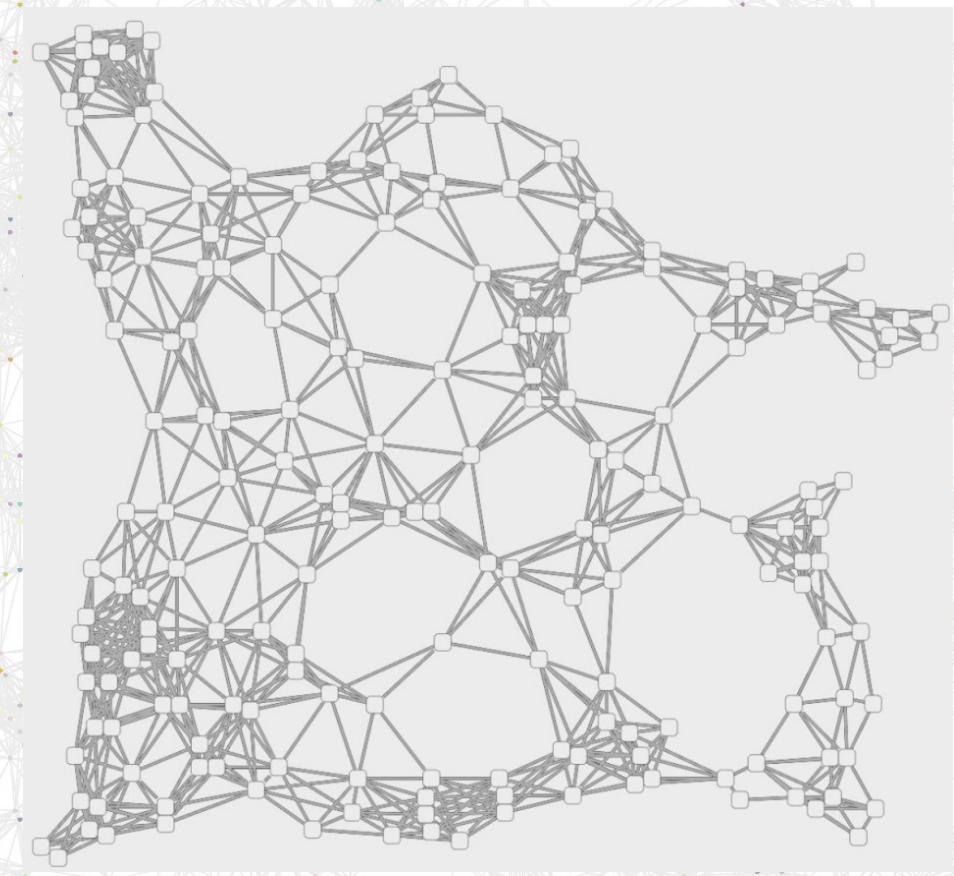
- a set of nodes V
  - called “individuals”
- a set of edges $E \in V \times V$
  - to represent “relations”

Definitions

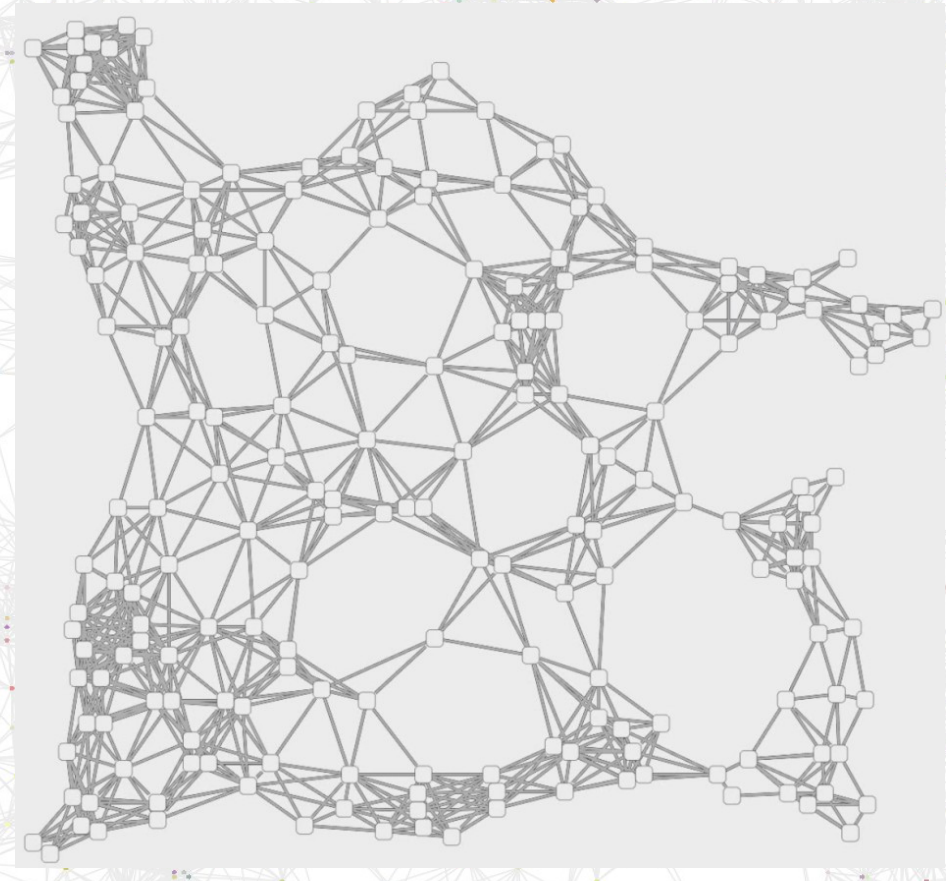
Propagation in a network – as a social process



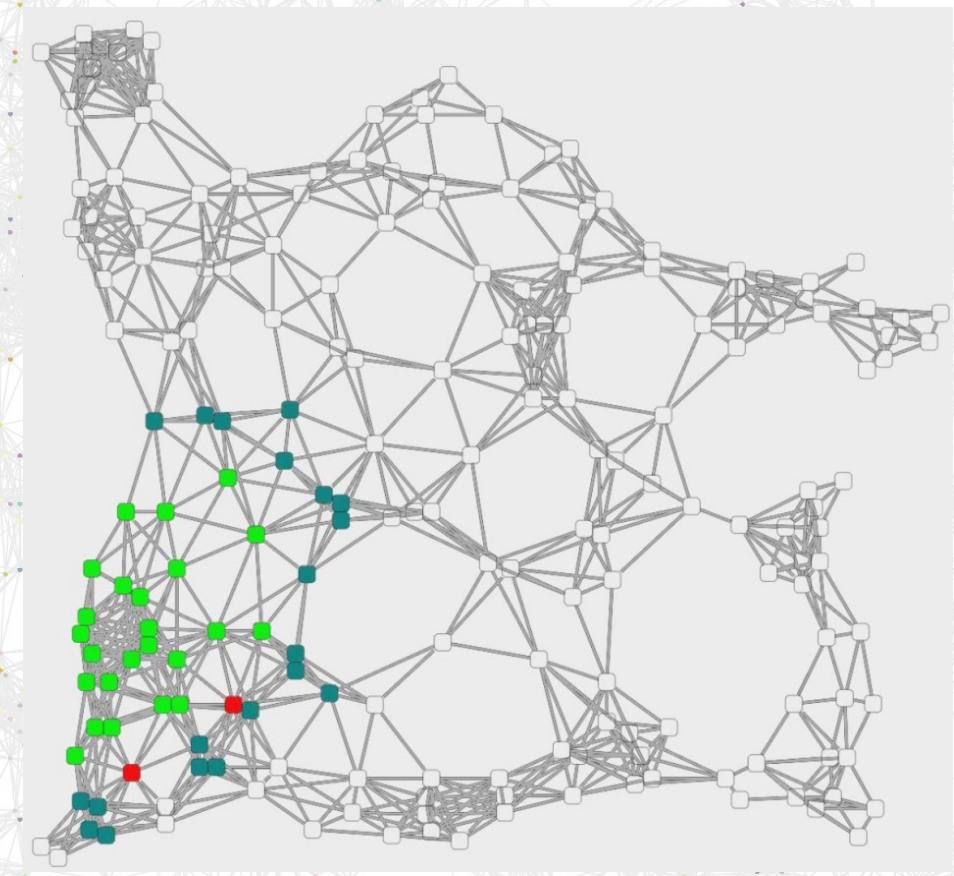
- An individual performs an action
- Her/his neighbours are informed and choose to perform the same action
- The process repeats itself
- Decisions can depend on influences, vulnerabilities or resistances between neighbours



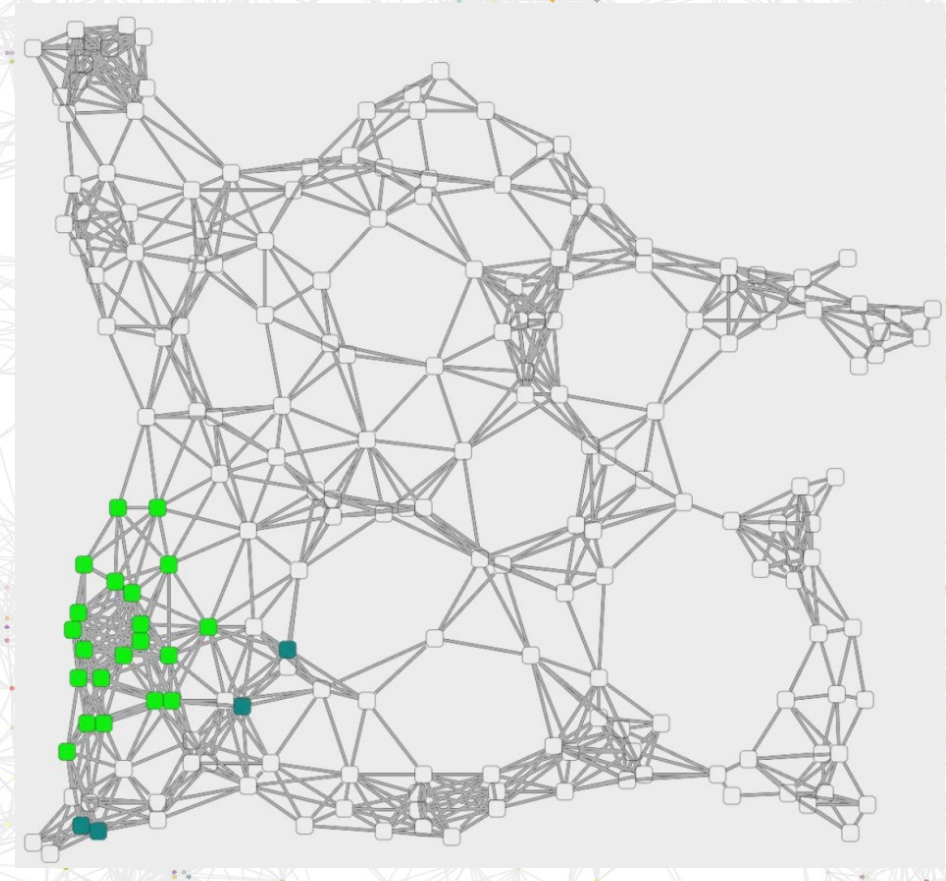
Probabilistic cascade model simulation



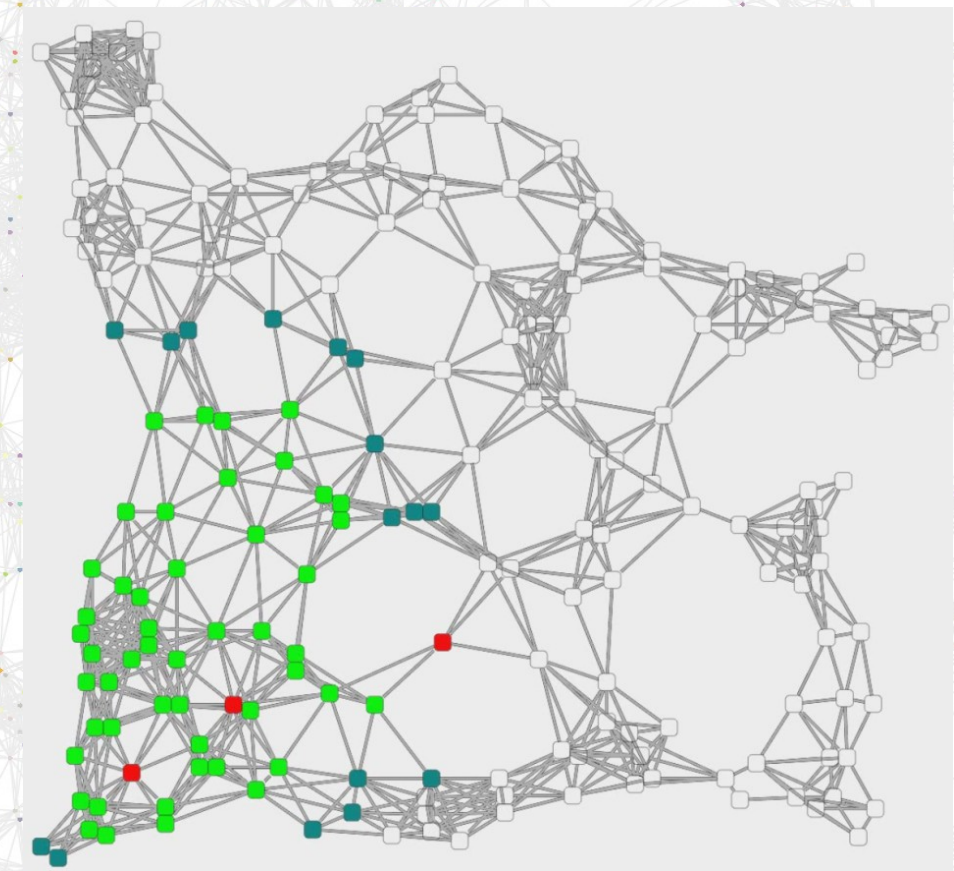
Linear threshold model simulation



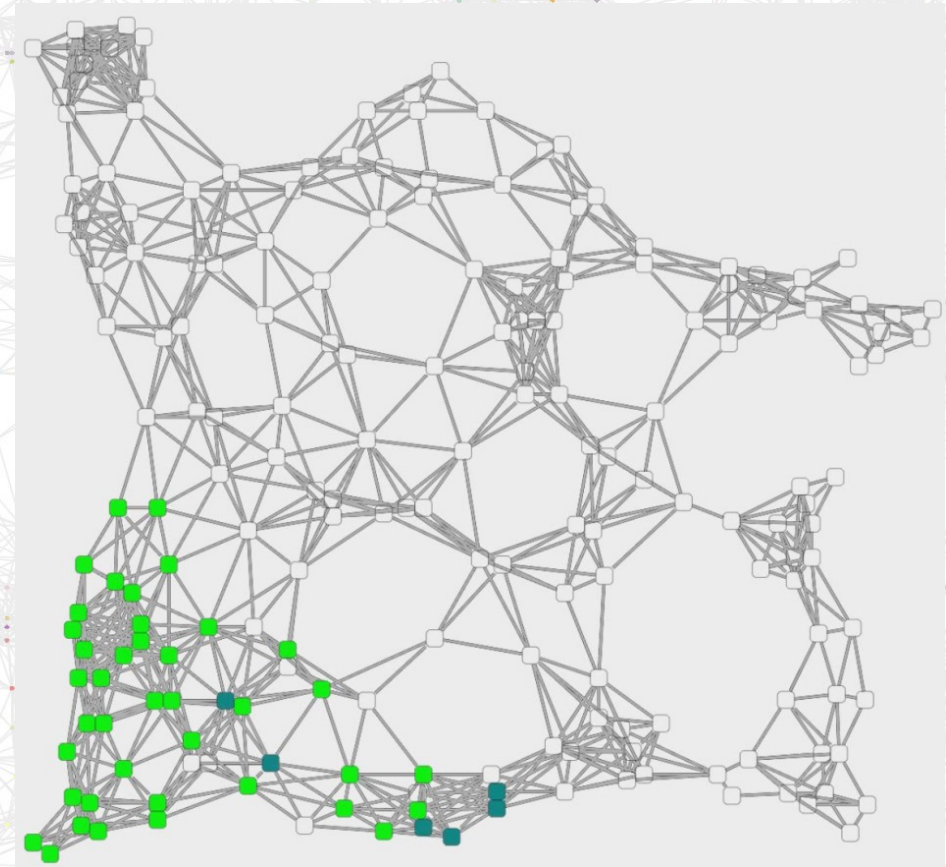
Probabilistic cascade model simulation



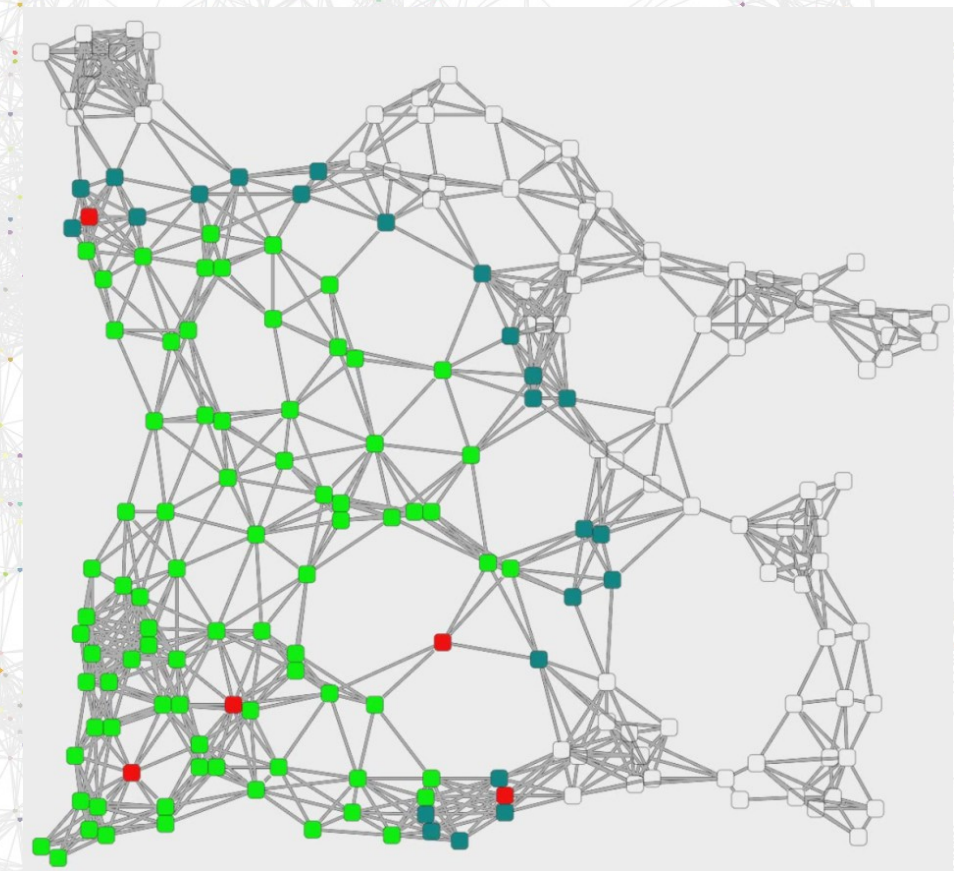
Linear threshold model simulation



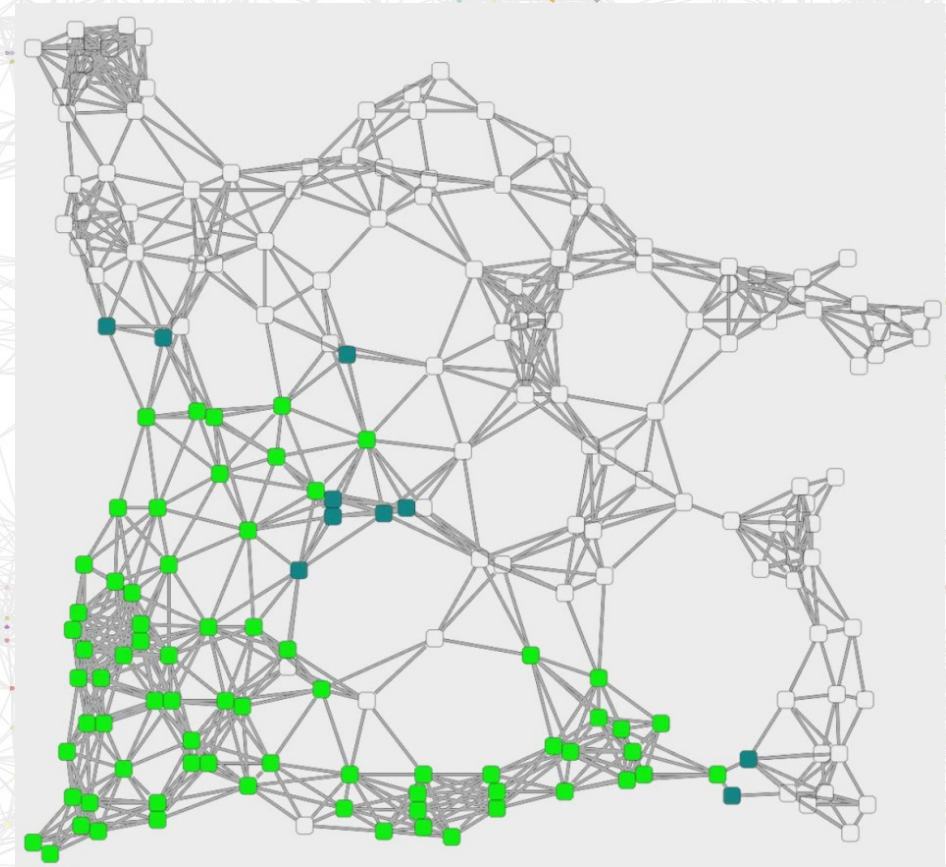
Probabilistic cascade model simulation



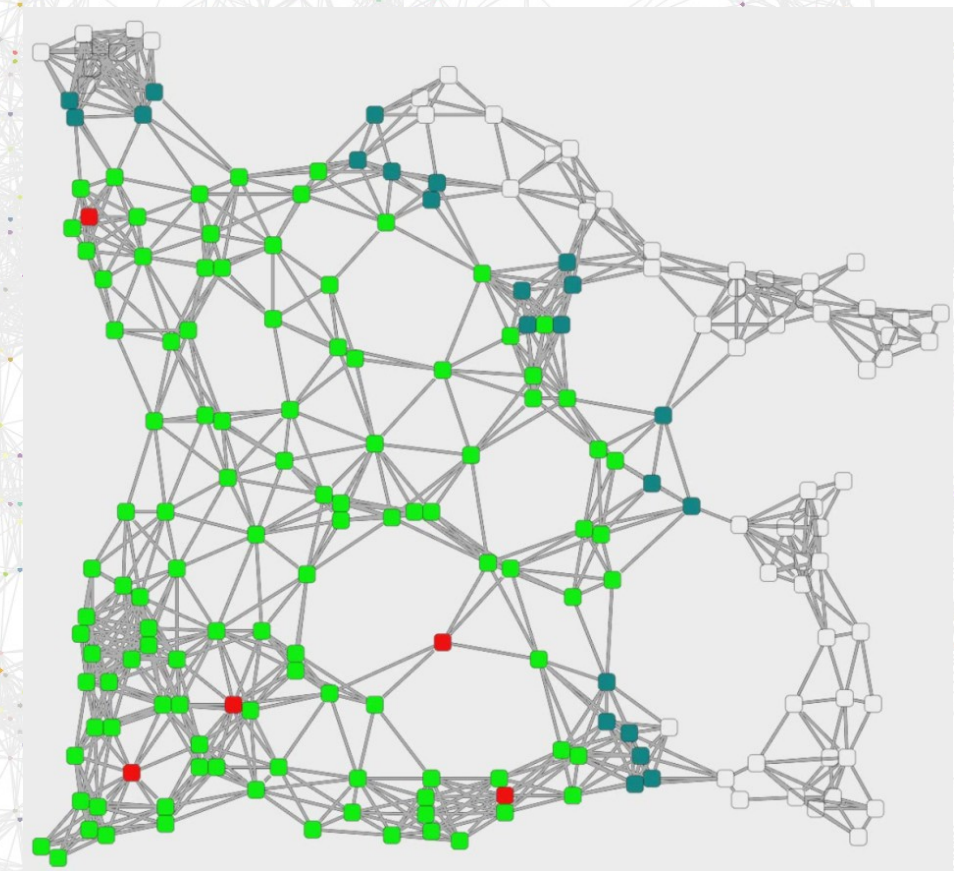
Linear threshold model simulation



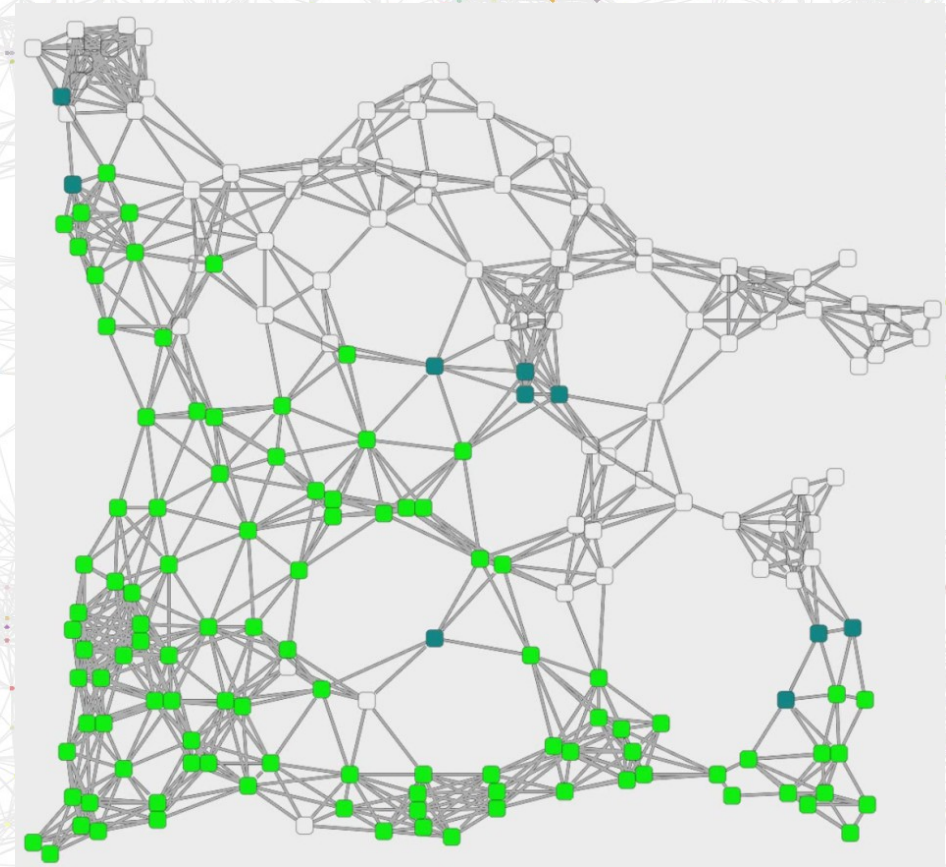
Probabilistic cascade model simulation



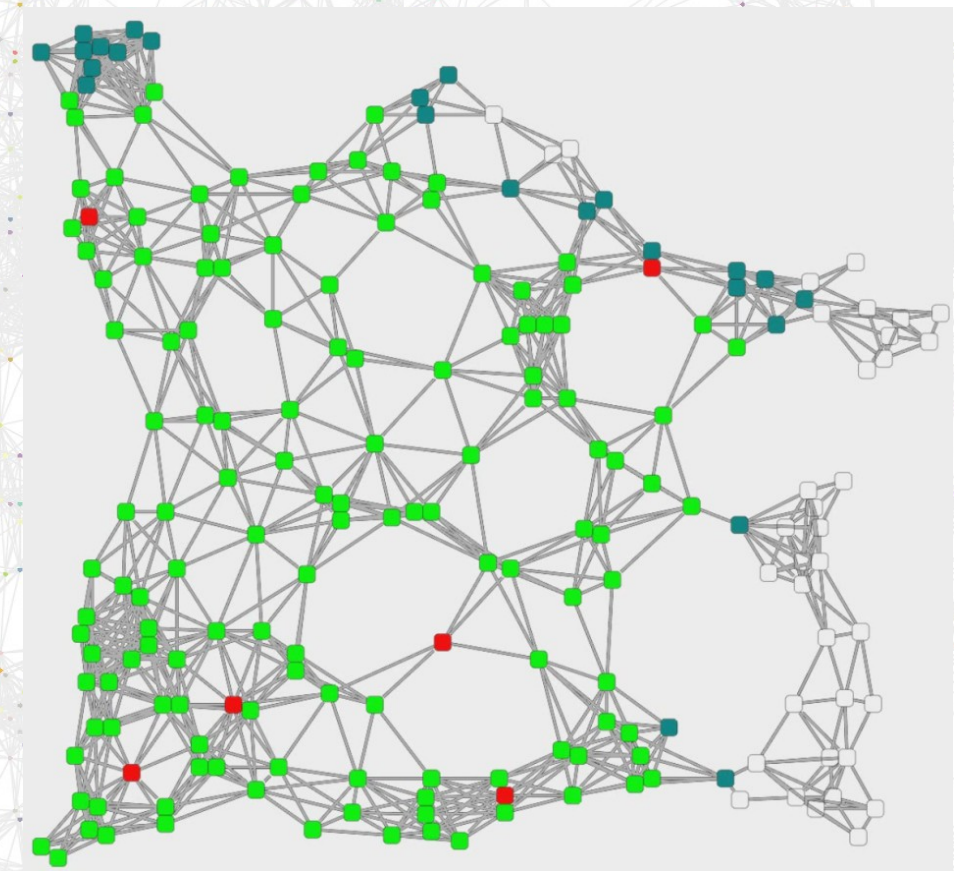
Linear threshold model simulation



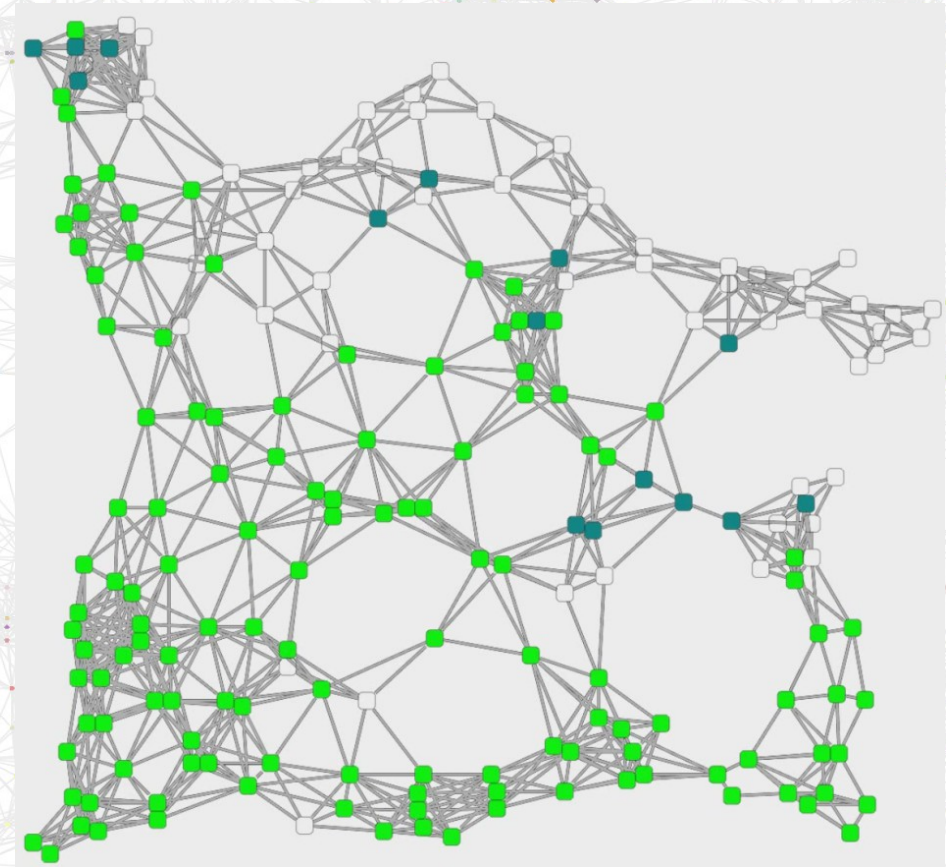
Probabilistic cascade model simulation



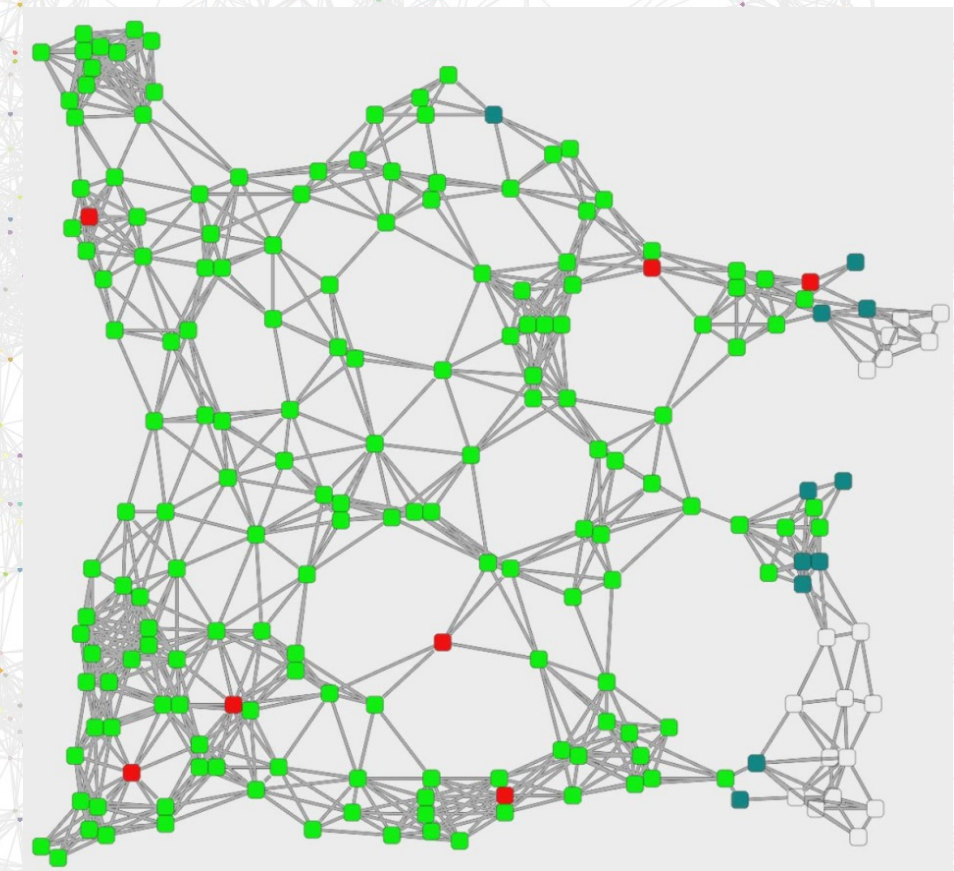
Linear threshold model simulation



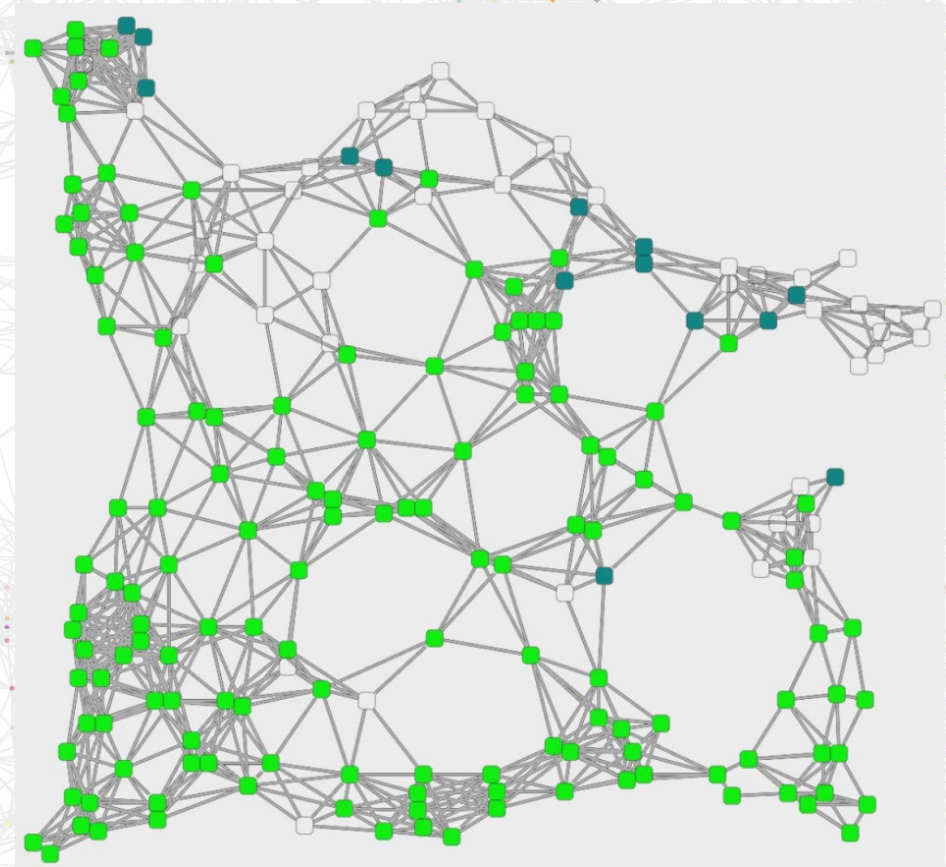
Probabilistic cascade model simulation



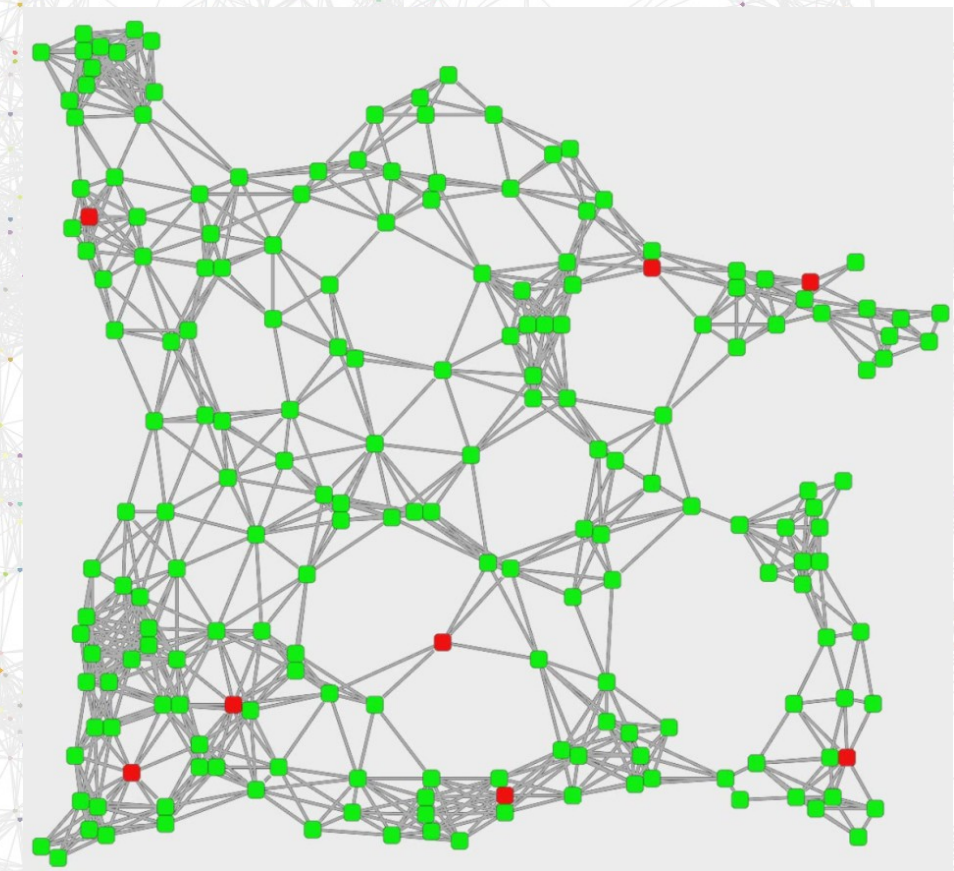
Linear threshold model simulation



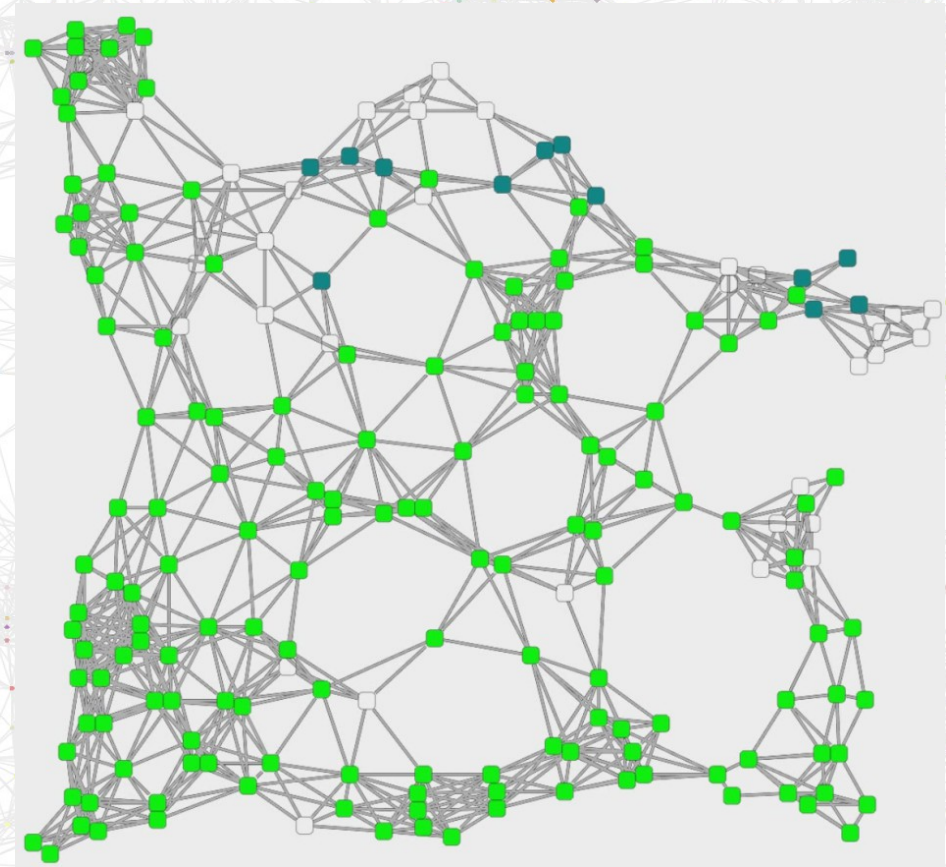
Probabilistic cascade model simulation



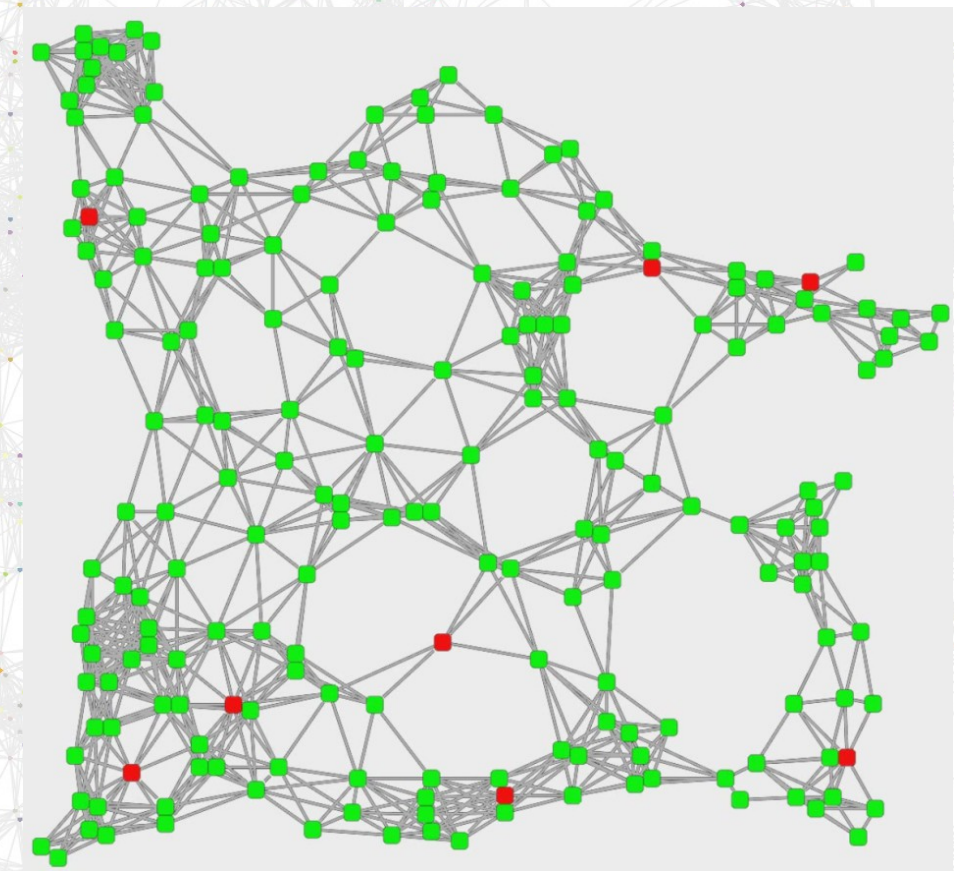
Linear threshold model simulation



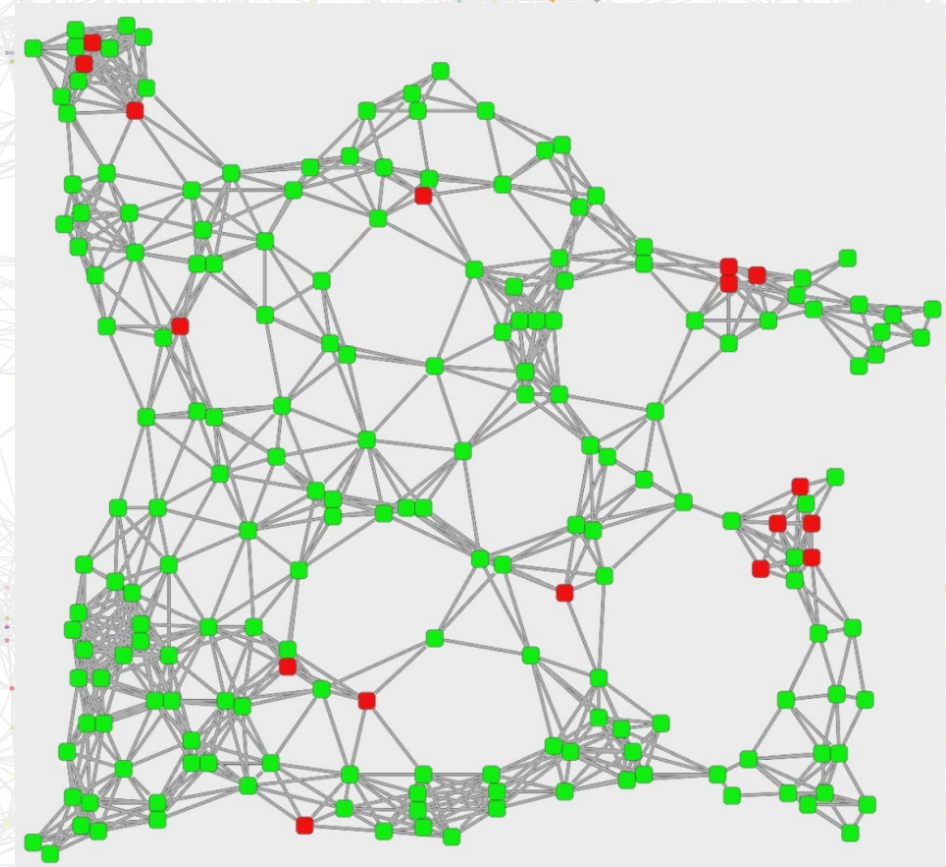
Probabilistic cascade model simulation



Linear threshold model simulation



Probabilistic cascade model simulation



Linear threshold model simulation

Definitions

Selected references:

- Threshold models

  Bertuzzo *et al. (2010)*, Dodds *et* al. (2005), Goyal *et al.* (2012), Granovetter (1978), Watts (2002)…

- Cascade models

  Chen W. *et al.* (2011), Gomez-Rodriguez *et* al. (2010), Payne *et al.* (2011), Richardson *et al.* (2002), Wonyeol *et al.* (2012)…

Model translation and rewrite rules

Propagation in a network from a graph theoretic perspective

- Social state (activated, influent) are encoded as node attributes
- The process acts locally, is asynchronous, distributed and follows some conditions
- This is where graph rewriting comes into play

Model translation and rewrite rules

Propagation in a network as a Graph Rewriting System

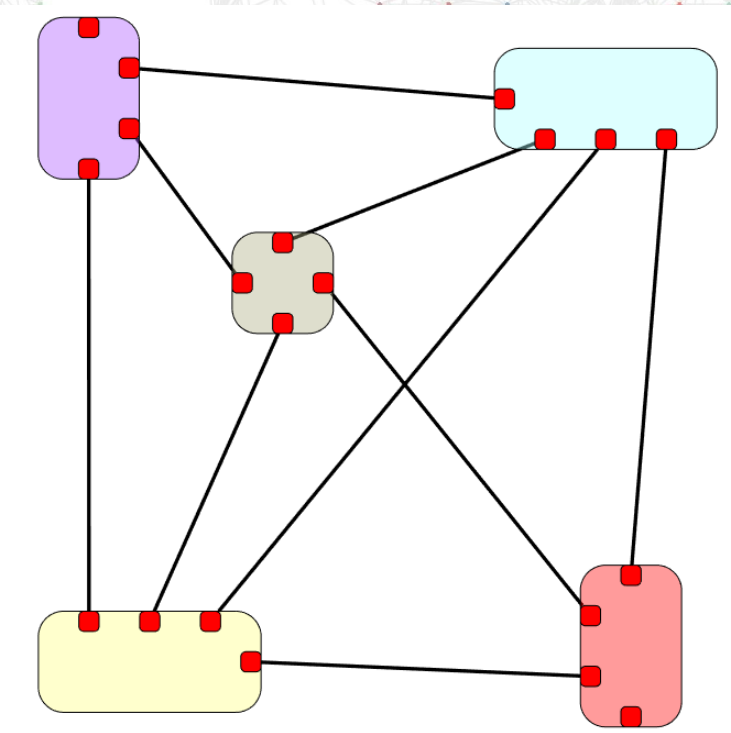
- Rules as a common paradigm to express the propagation models
- Each propagation paradigm (threshold, cascade) has its own ruleset and a strategy managing their application
- Modelling through Strategic Rewriting [Fernandez *et al.* (2014)]

Model translation and rewrite rules

Definition: Port graph with properties

[Fernandez *et al.* (2014)]

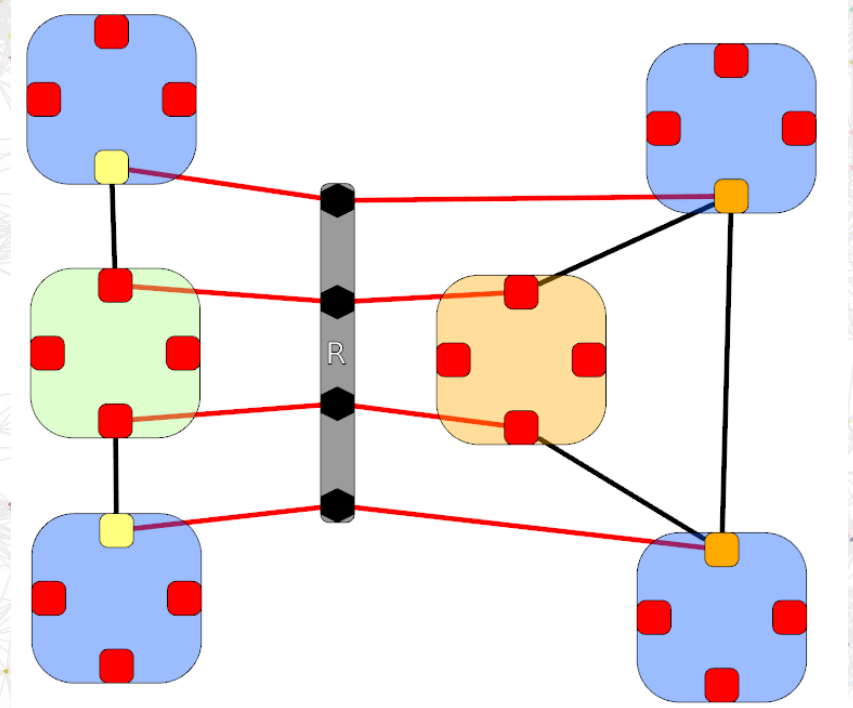
- $G=(N,P,E)$
- Ports are used as connection points
- Edges connect nodes through ports
- Each element possess a set of properties



Model translation and rewrite rules

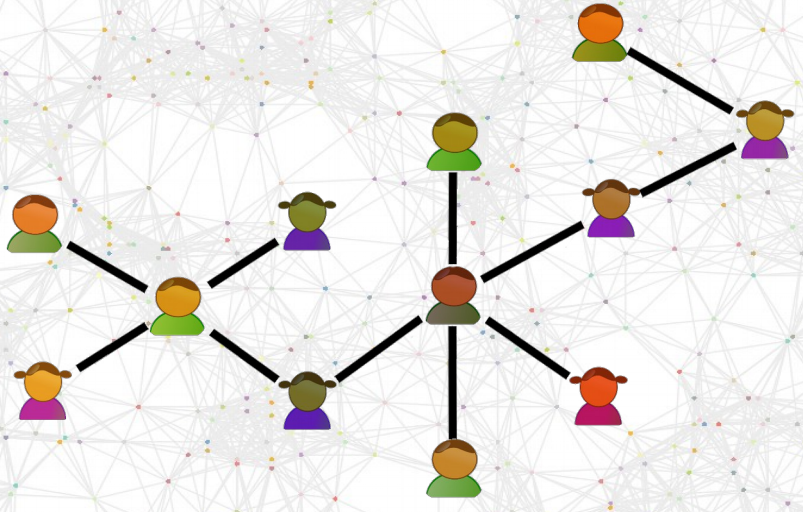
Definition: Port graph rewrite rule

- Symbolically written as
$$L \Rightarrow R$$
- LHS/RHS expressed as port graphs
- $\Rightarrow$ is a special node whose ports encode rewiring conditions to perform in rewriting (through red edges)



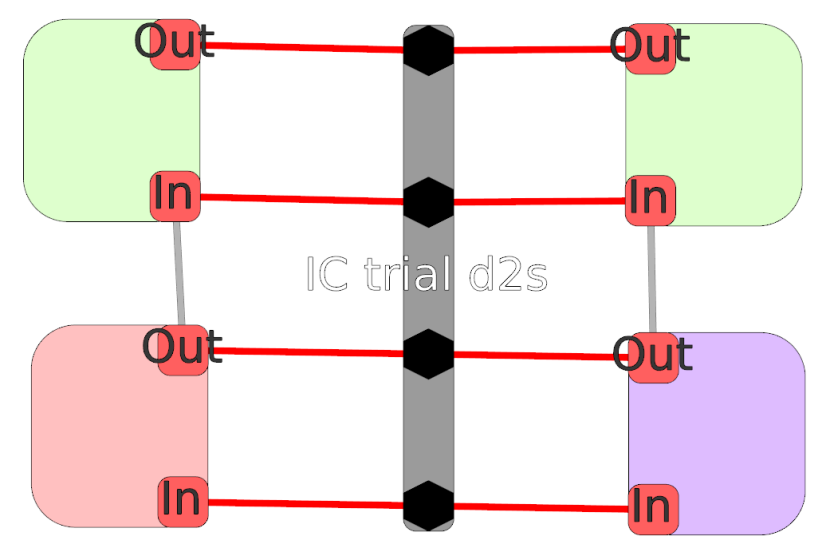
Model translation and rewrite rules

Example: Independent cascade model [Kempe *et al.* (2003)]



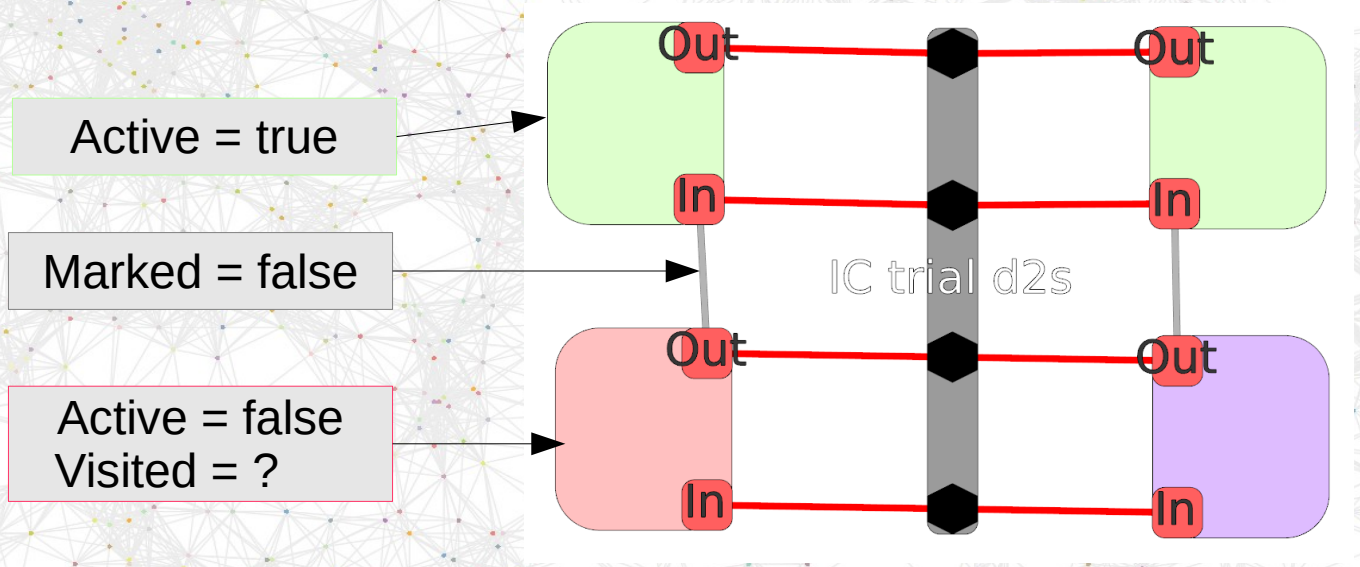
- Start with a set of influencers
- Influencers try (according to some probability) to influence their neighbours and recruit them as new influencers
- The process repeats until no more influencer can be recruited

Model translation and rewrite rules



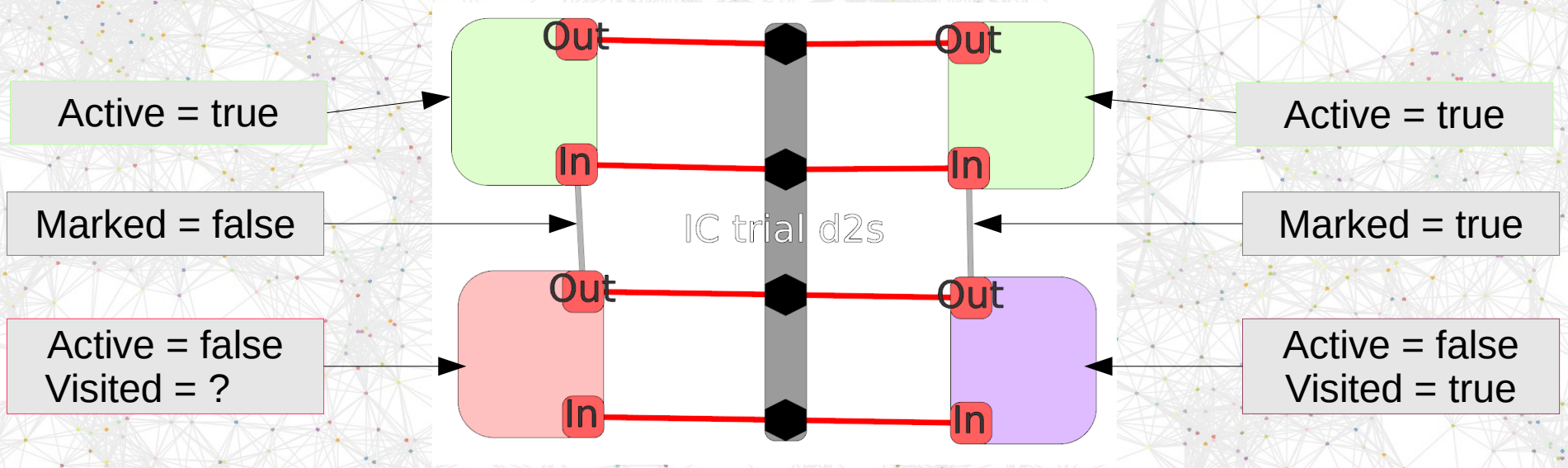
Rule 1: influence from a neighbour

Model translation and rewrite rules



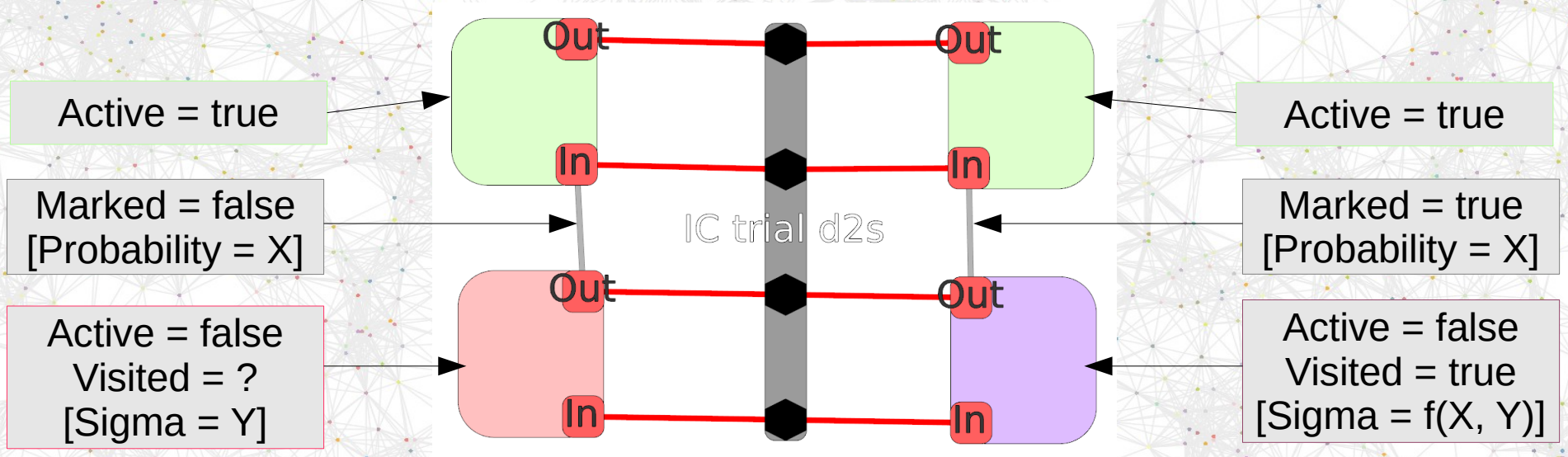
Rule 1: influence from a neighbour

Model translation and rewrite rules



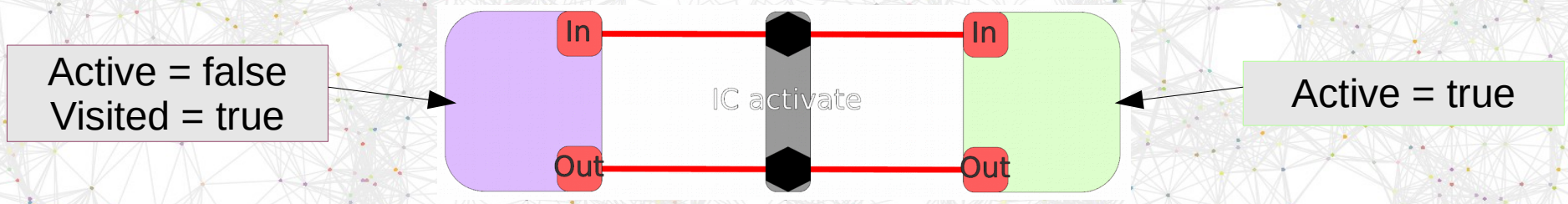
Rule 1: influence from a neighbour

Model translation and rewrite rules



Rule 1: influence from a neighbour

Model translation and rewrite rules



Rule 2: node activation

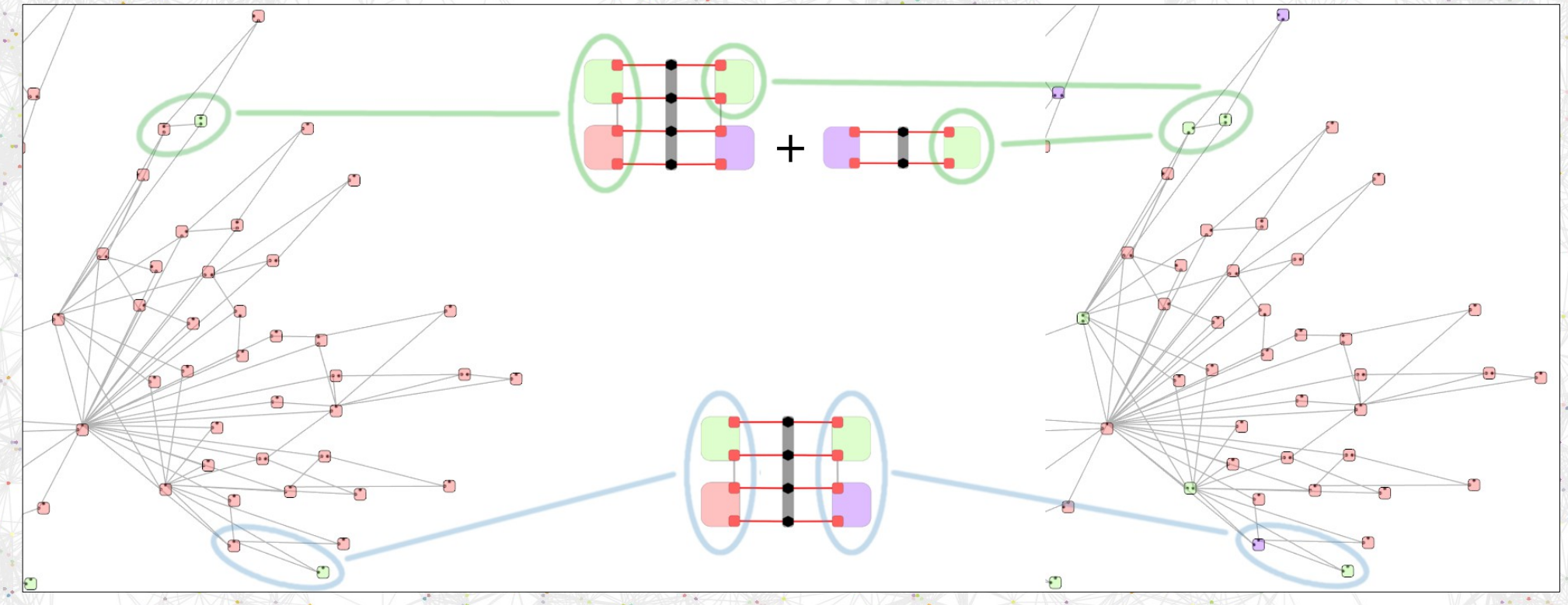
Model translation and rewrite rules

Definition: Strategy

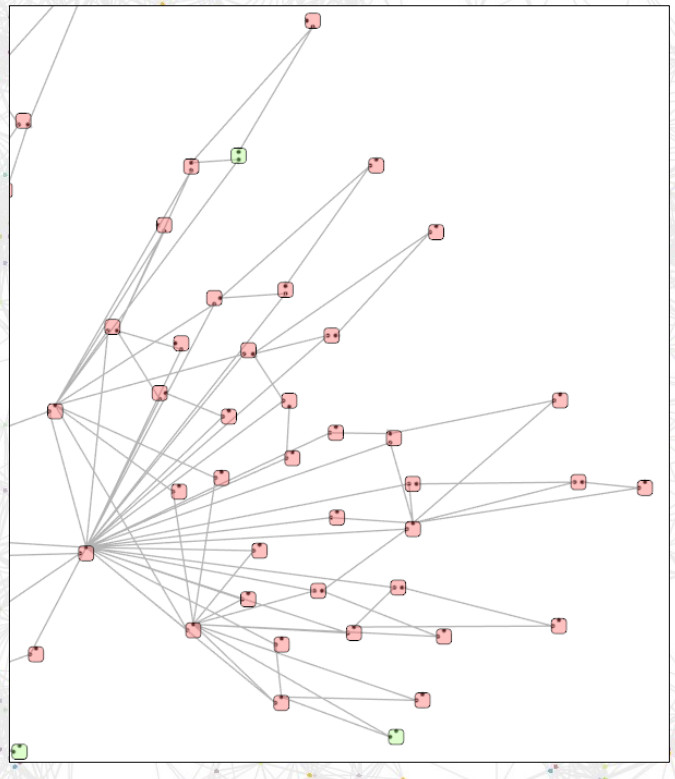
- Manage the rules' application order
- Express control (*repeat*, *if-then-else*, *while-do*, …)

- Use a *located graph* with P*osition* and B*anned* subgraphs:
  - *Position* represents the subgraph where rewriting may take place
  - *Banned* represents the subgraph where rewriting is forbidden

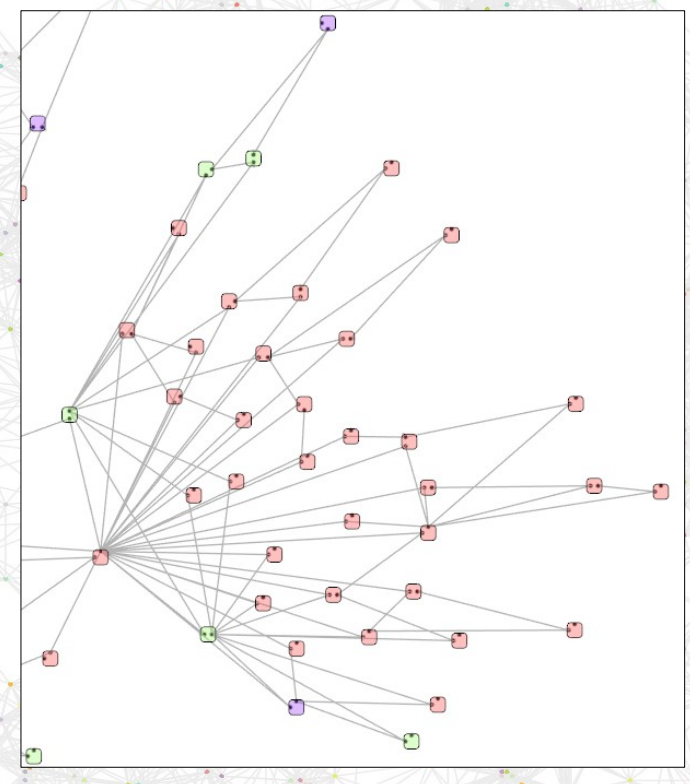
Model translation and rewrite rules



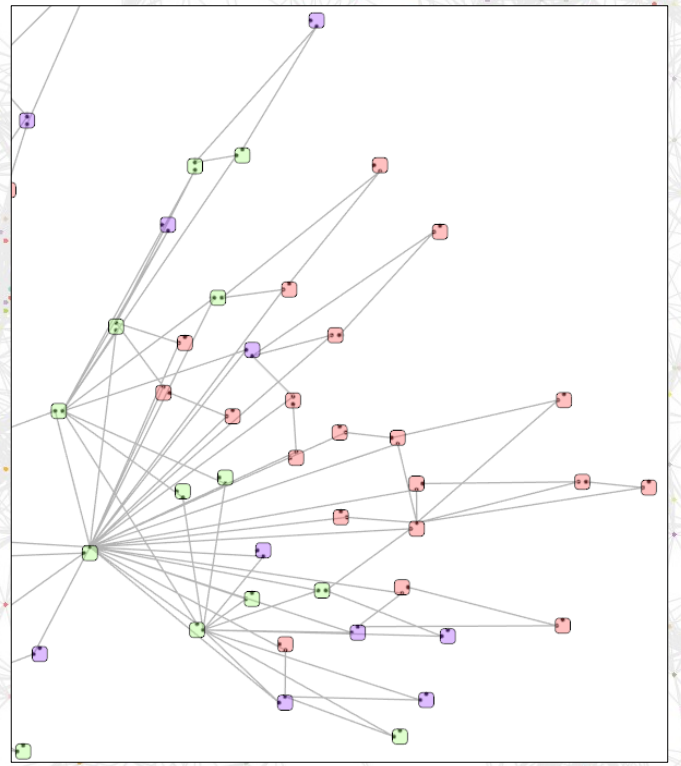
Model translation and rewrite rules



Step 1

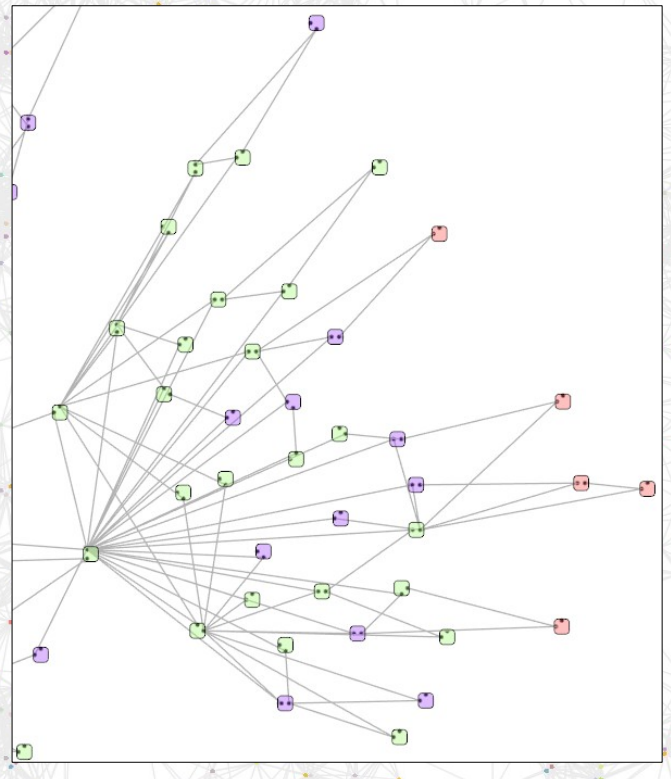


Step 2

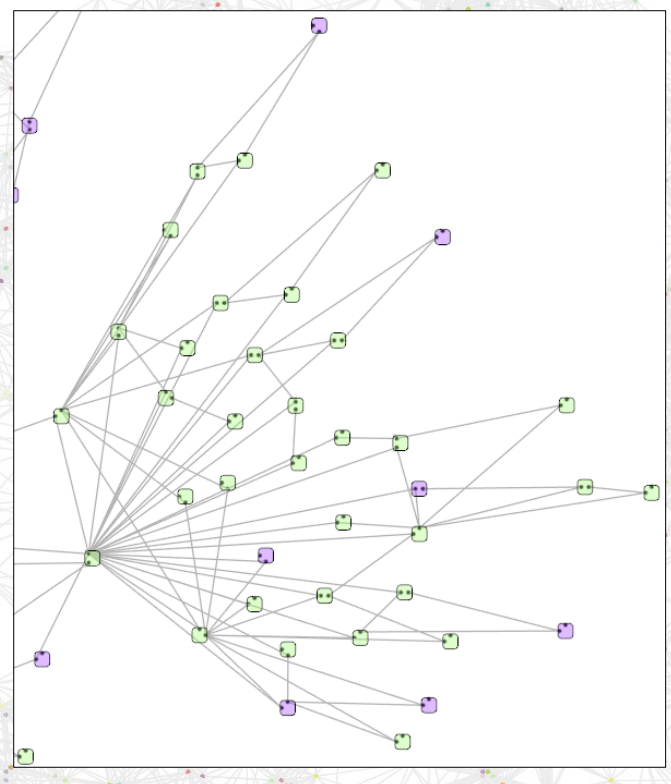


Step 3

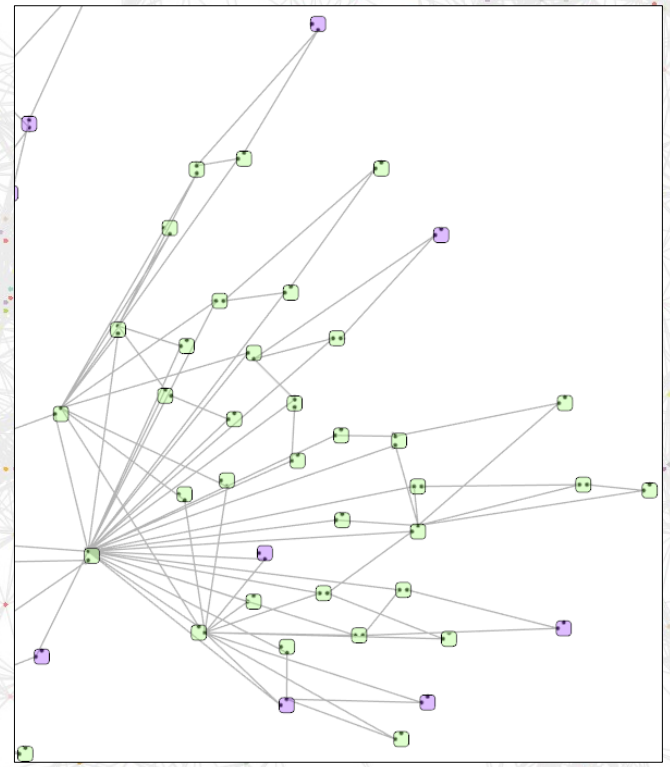
Model translation and rewrite rules



Step 4

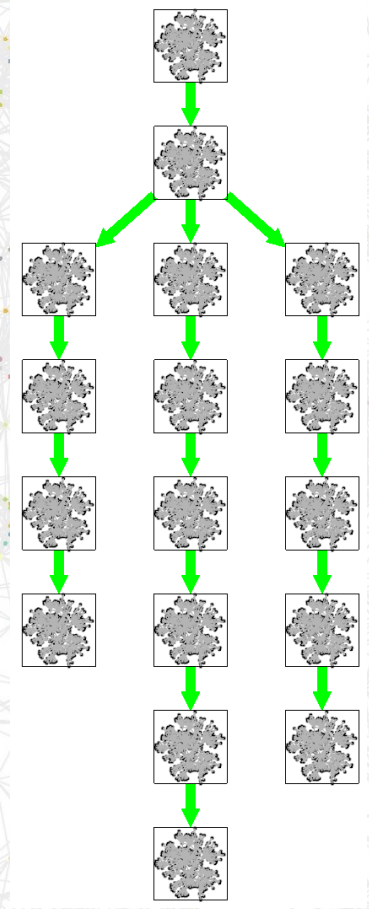


Step 5



Step 6

Analytic visualization and model comparison



- Successive applications of rules
- Keep track of the previously computed simulations
- Use the derivation tree during comparative analysis

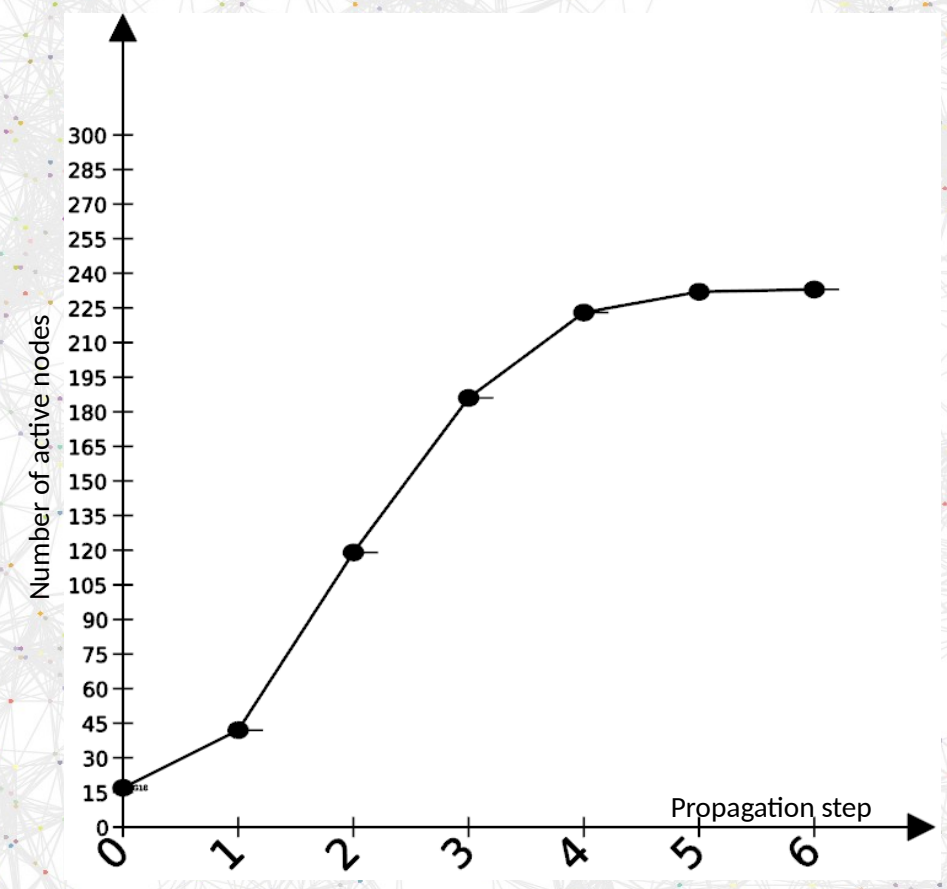
[Pinaud *et al.* (2012)]

Analytic visualization and model comparison

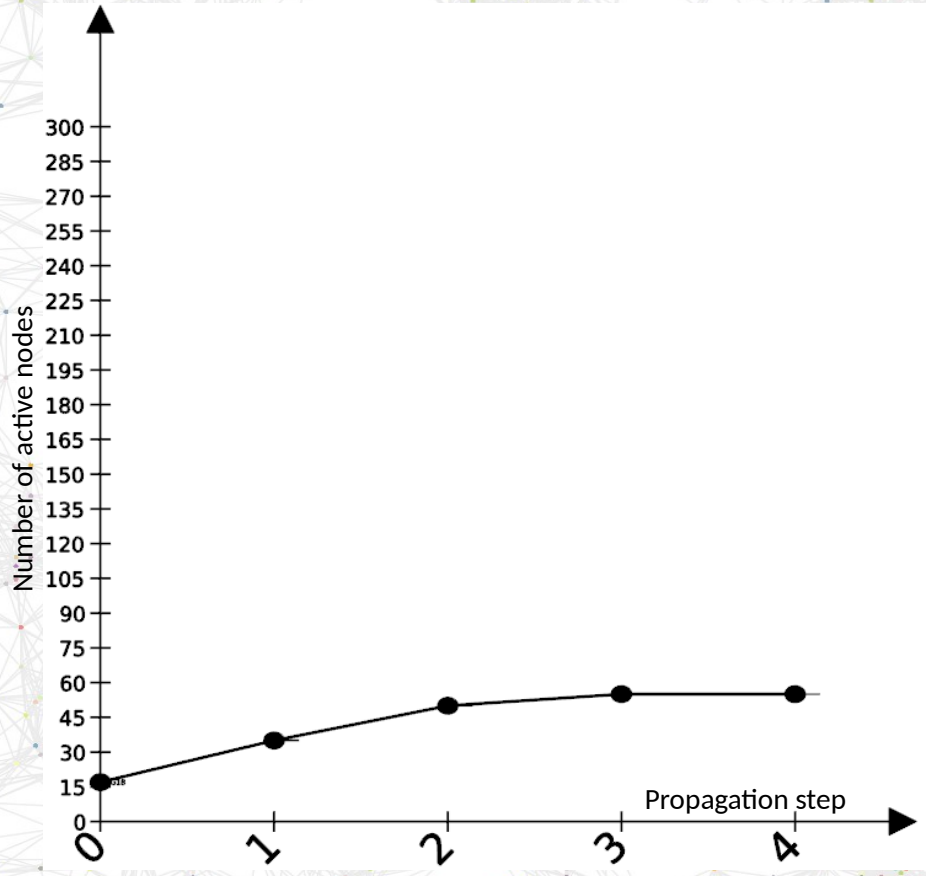
Metrics: used to measure the propagation evolution

- *Propagation speed*: estimated by the number of active nodes at a given step
- *Acknowledgment speed*: estimated by the number of visited nodes at a given step
- *Propagation efficiency*: ratio of activated nodes at step *t* against those visited at *t-1*

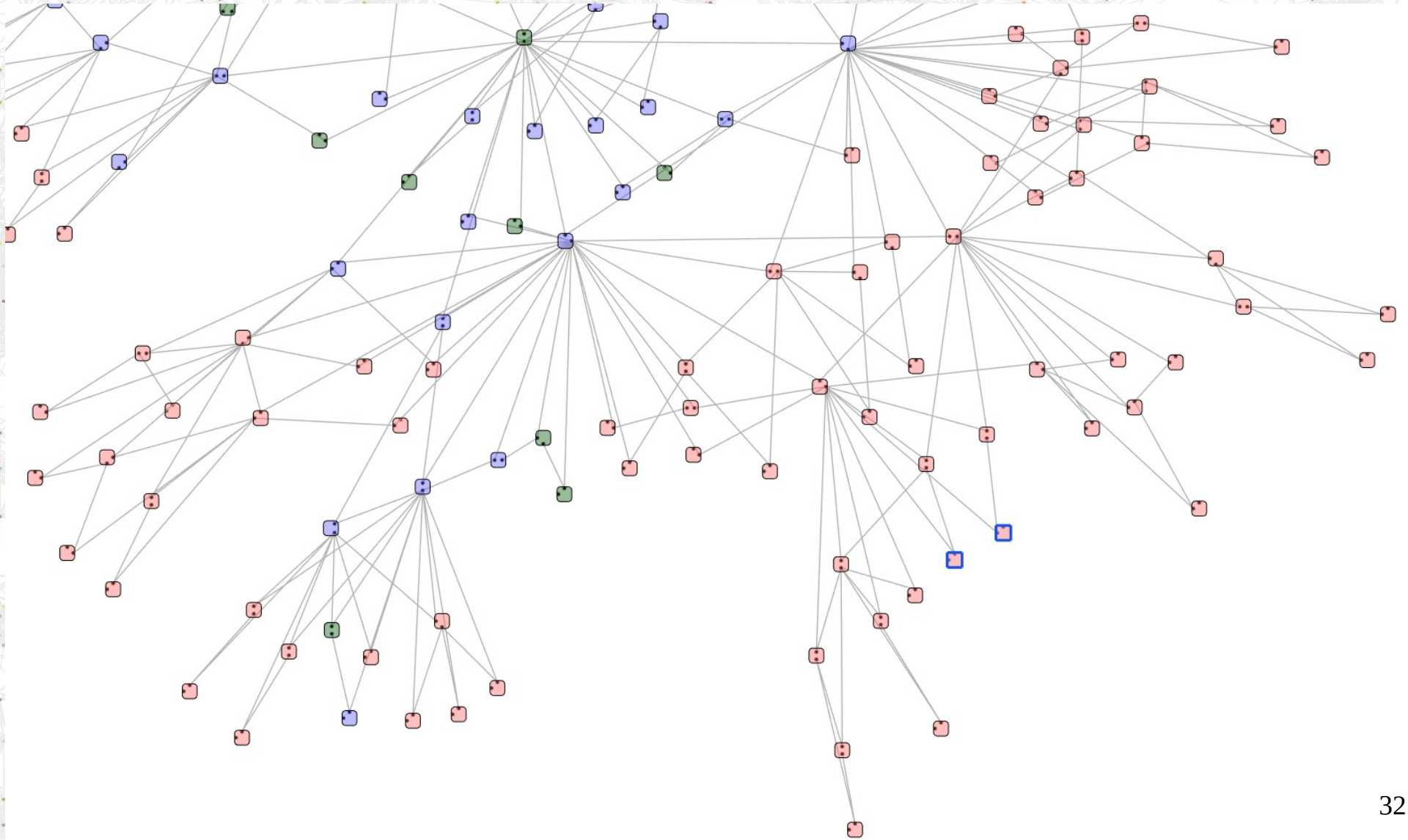
Propagation speed



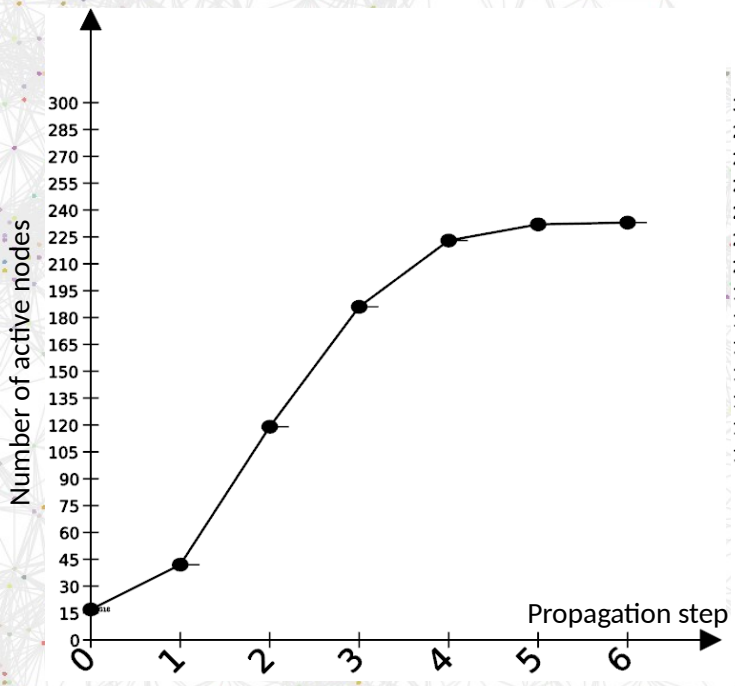
Independent cascade



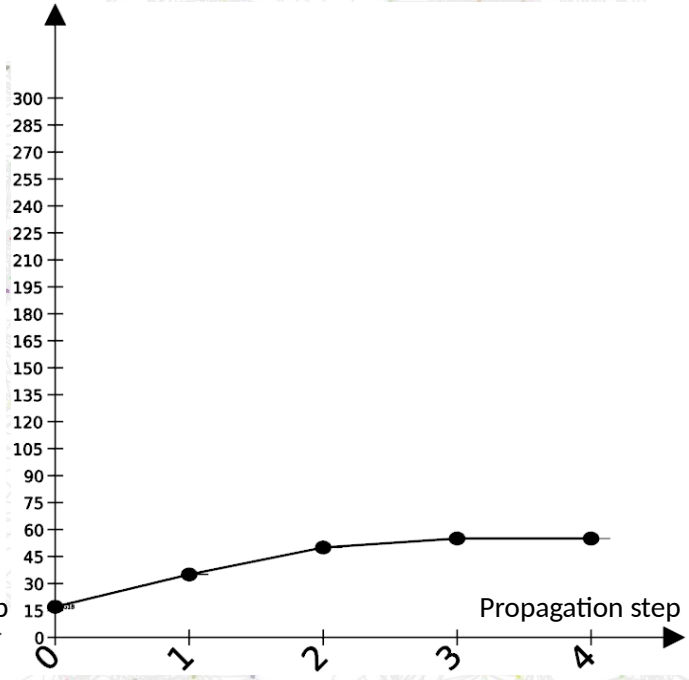
Linear threshold model



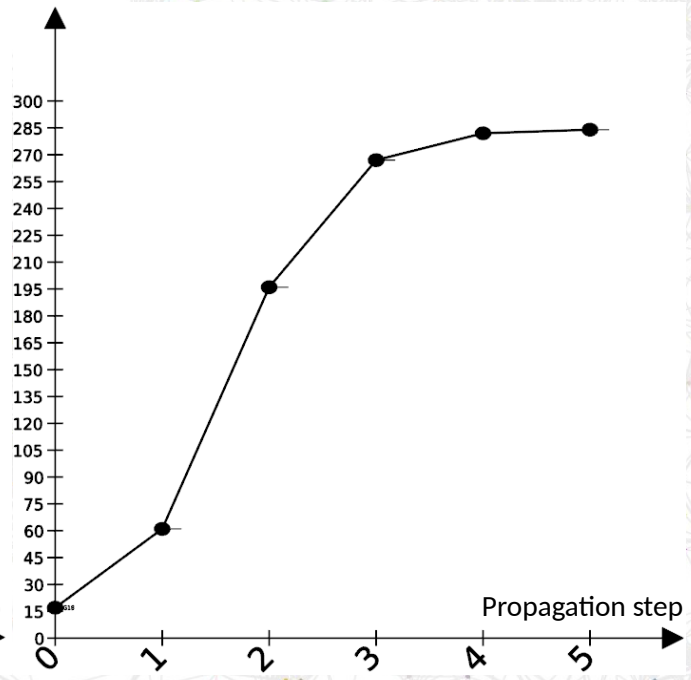
Propagation speed



Independent cascade

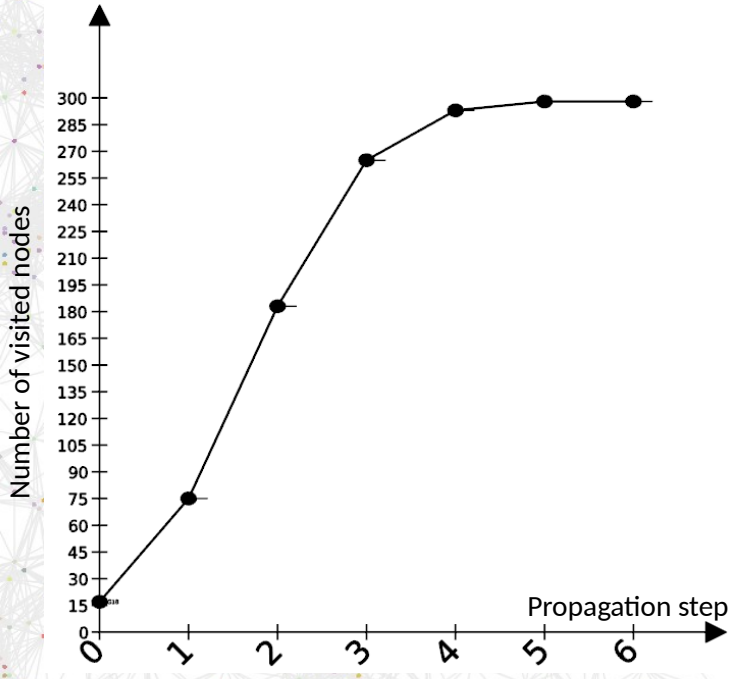


Linear threshold model

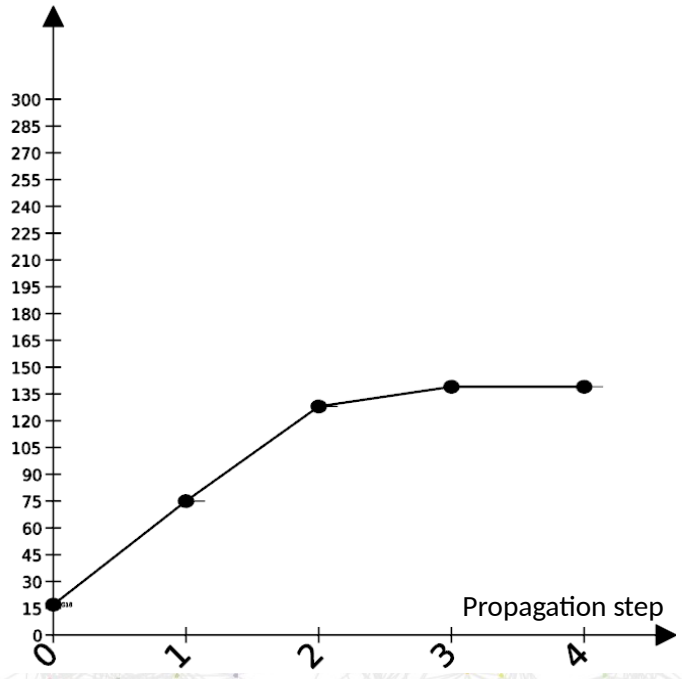


Linear threshold model (reinforced influences)

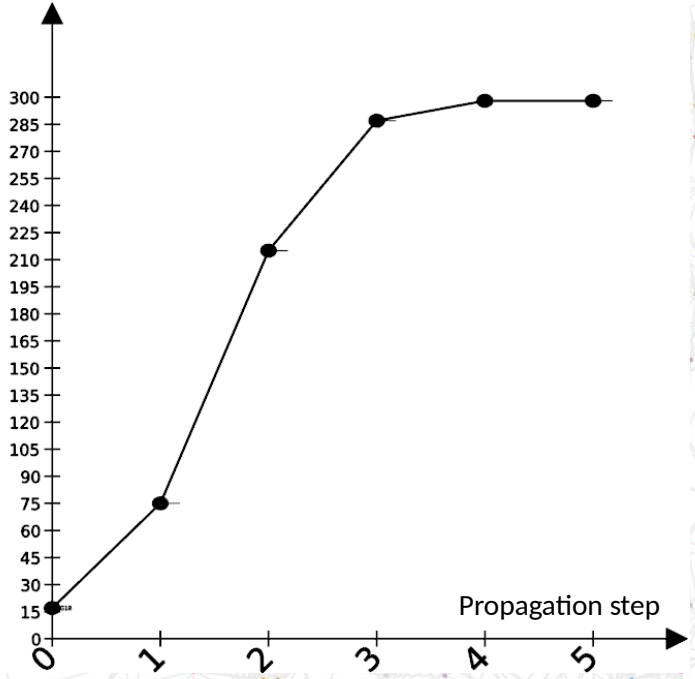
Acknowledgment speed



Independent cascade



Linear threshold model



Linear threshold model (reinforced influences)

To conclude

- We have used graph rewriting as a common language to express propagation models
- Analyze and compare the models precisely by storing the propagation evolution
- Results can be visually investigated to help enforce influence maximization
- Several metrics available to perform analysis

Future work

- Extend to additional models
- Explore other visual encodings for scalability (Matrix views…)
- Management of time-dependent attributes evolving along the propagation (influence exhaustion, media induced fashion…)
- Joint use of propagation and topological modifications
- Application to different domains (power distribution, network security, epidemiology, financial crisis)

References

- Goyal, A., F. Bonchi, and L. V. Lakshmanan (2010). Learning influence probabilities in social networks. In 3rd ACM Int. Conf. on Web Search and Data Mining, WSDM ’10, pp. 241–250

- Kempe, D., J. Kleinberg, and É. Tardos (2003). Maximizing the spread of influence through a social network. In Proc. of the 9th ACM SIGKDD Int. Conf. on Knowledge Discovery and Data Mining, KDD ’03, pp. 137–146

- Fernandez, M., H. Kirchner, and B. Pinaud (2014). Strategic Port Graph Rewriting : An Interactive Modelling and Analysis Framework. In D. Bošnački, S. Edelkamp, A. L. Lafuente, et A. Wijs (Eds.), GRAPHITE 2014, Volume 159 of EPTCS, pp. 15–29

- Pinaud, B., G. Melançon, and J. Dubois (2012). Porgy : A visual graph rewriting environment for complex systems. Computer Graphics Forum 31(3), 1265–1274.

Thanks for your attention.