# Self-healing percolation

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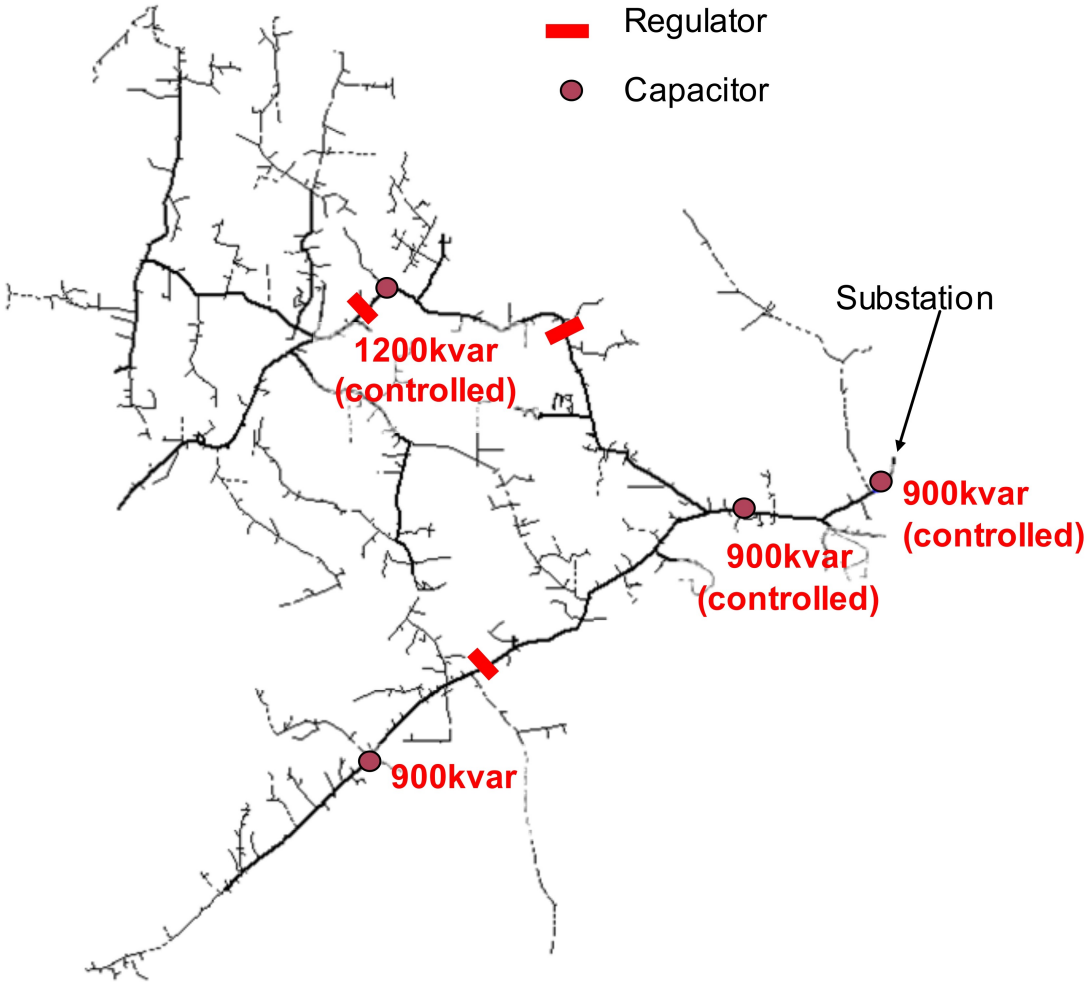
# Summary

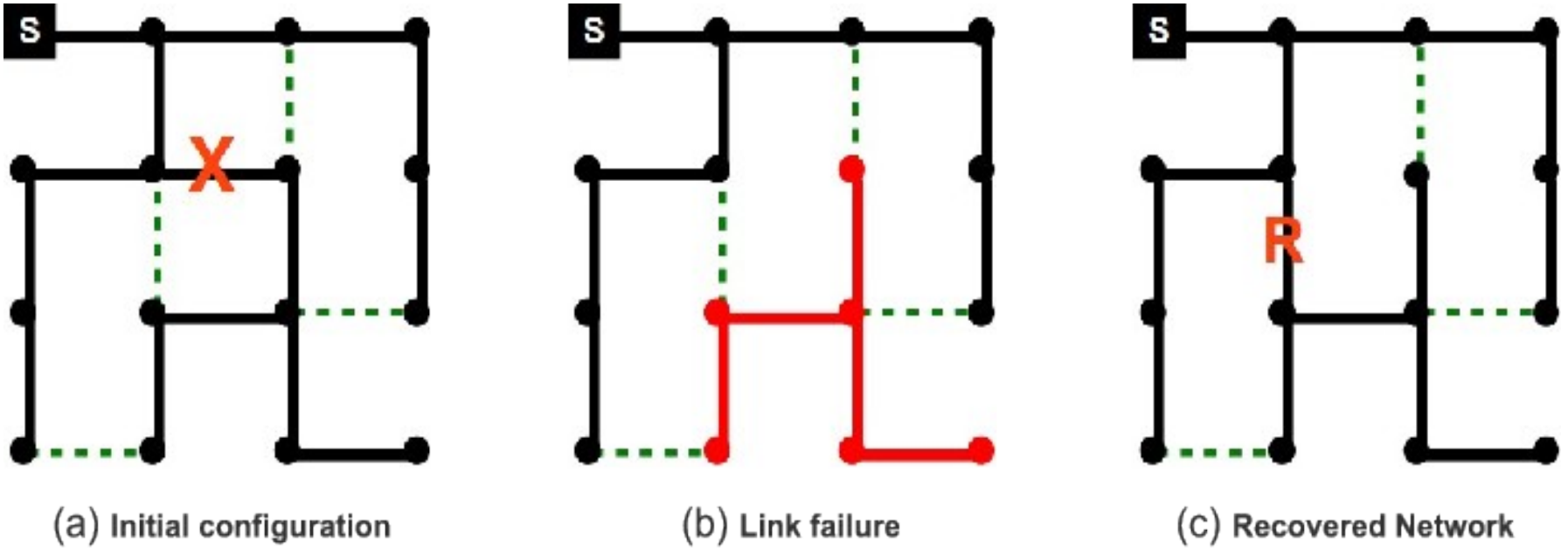
- Self Healing Networks
- Cavity Method
- Self Healing Percolation
- Perspectives

# Self Healing Networks

# IEEE test feeder (US, medium voltage)



# Self-healing Networks



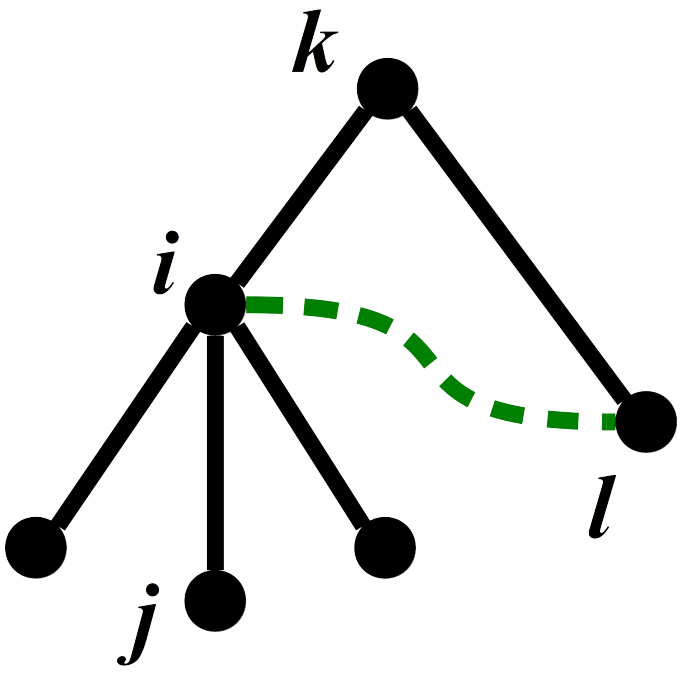

(a) Initial configuration (b) Link failure (c) Recovered Network

- Inspired by real distribution networks
- Routing Algorithms for Smart Networks

**Self-Healing Networks: Redundancy and Structure**
**PLoS ONE 9 (2), e87986**

# Cavity Method

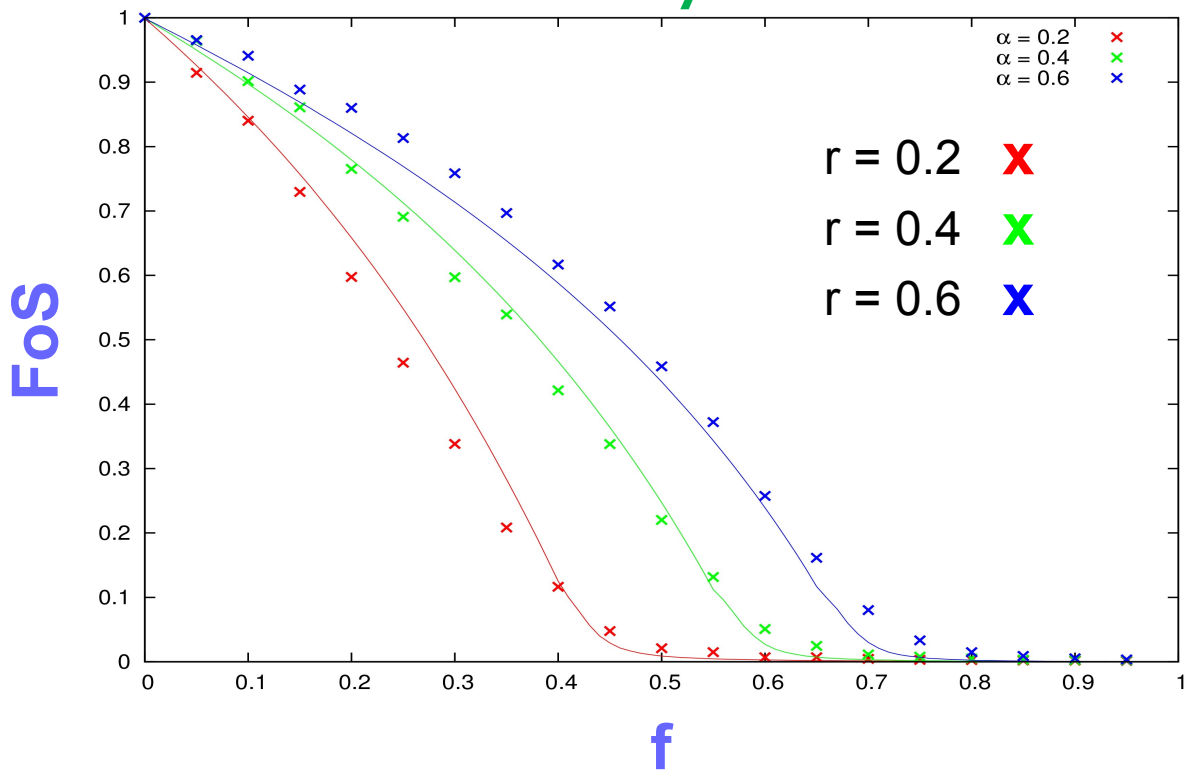
# Message Passing & Cavity Equations




Self consistent equation set for:

- $down_{ij}$ probability of being connected when son $j$ fails
- $up_{ik}$ probability of being connected when father $k$ fails
- $redund_{il}$ probability of being connected when neighbour $l$ fails

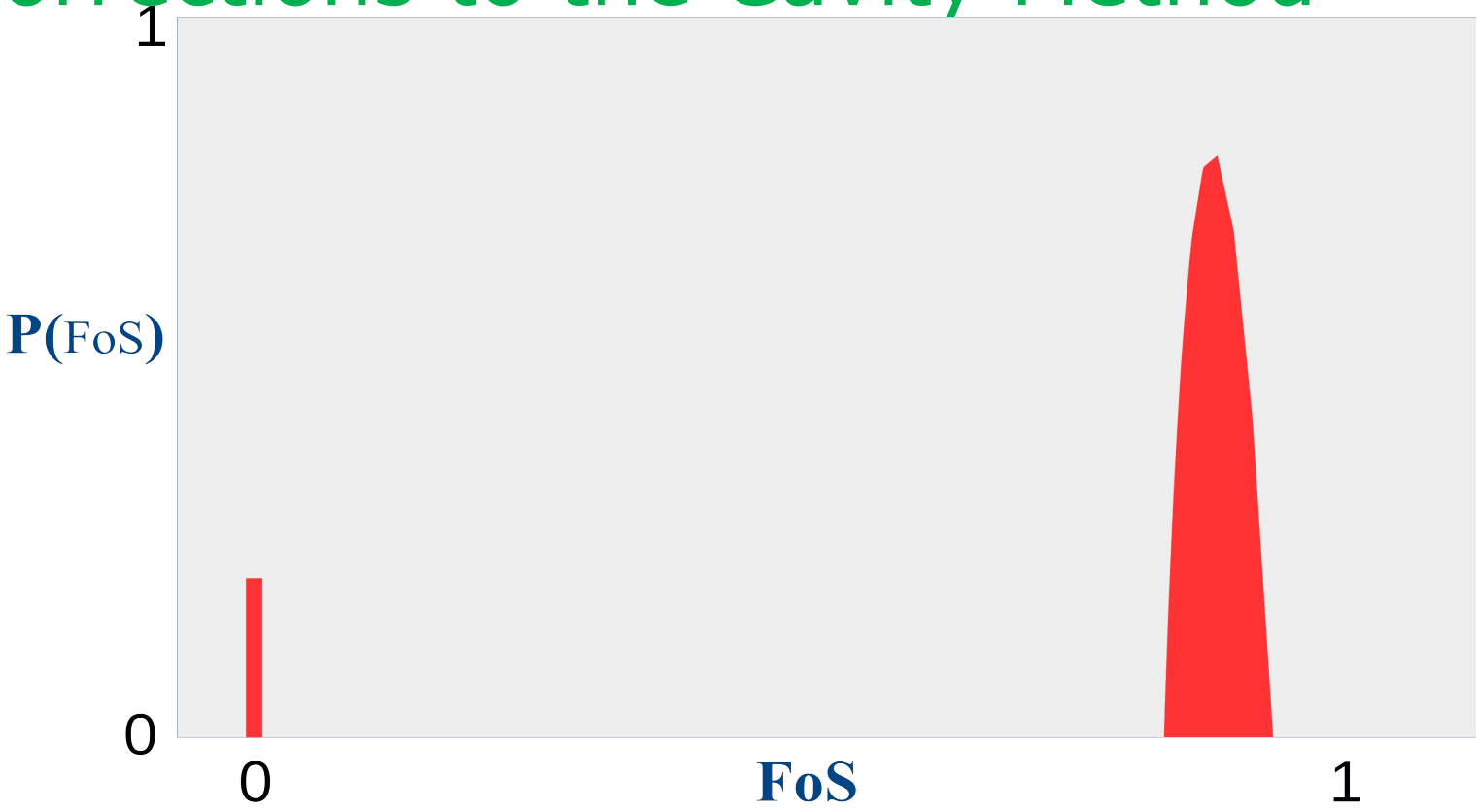
# Simulations & theory




**r** recoveries – **f** failures – **FoS** fraction of served nodes

Self-consistent equations for messages running on the edges of the tree and on redundant edges

# Corrections to the Cavity Method

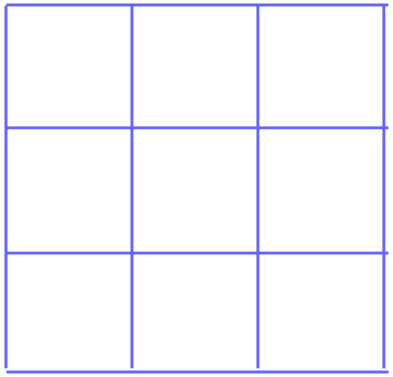



Two kinds of solutions:

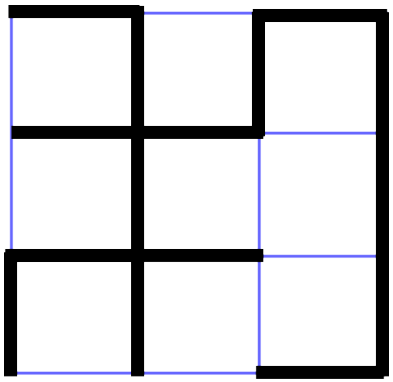
- Blackouts
- Decrease of the **FoS**

# Self-healing Percolation

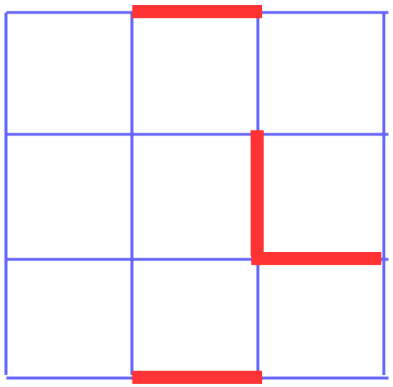
# Self-Healing percolation



World topology



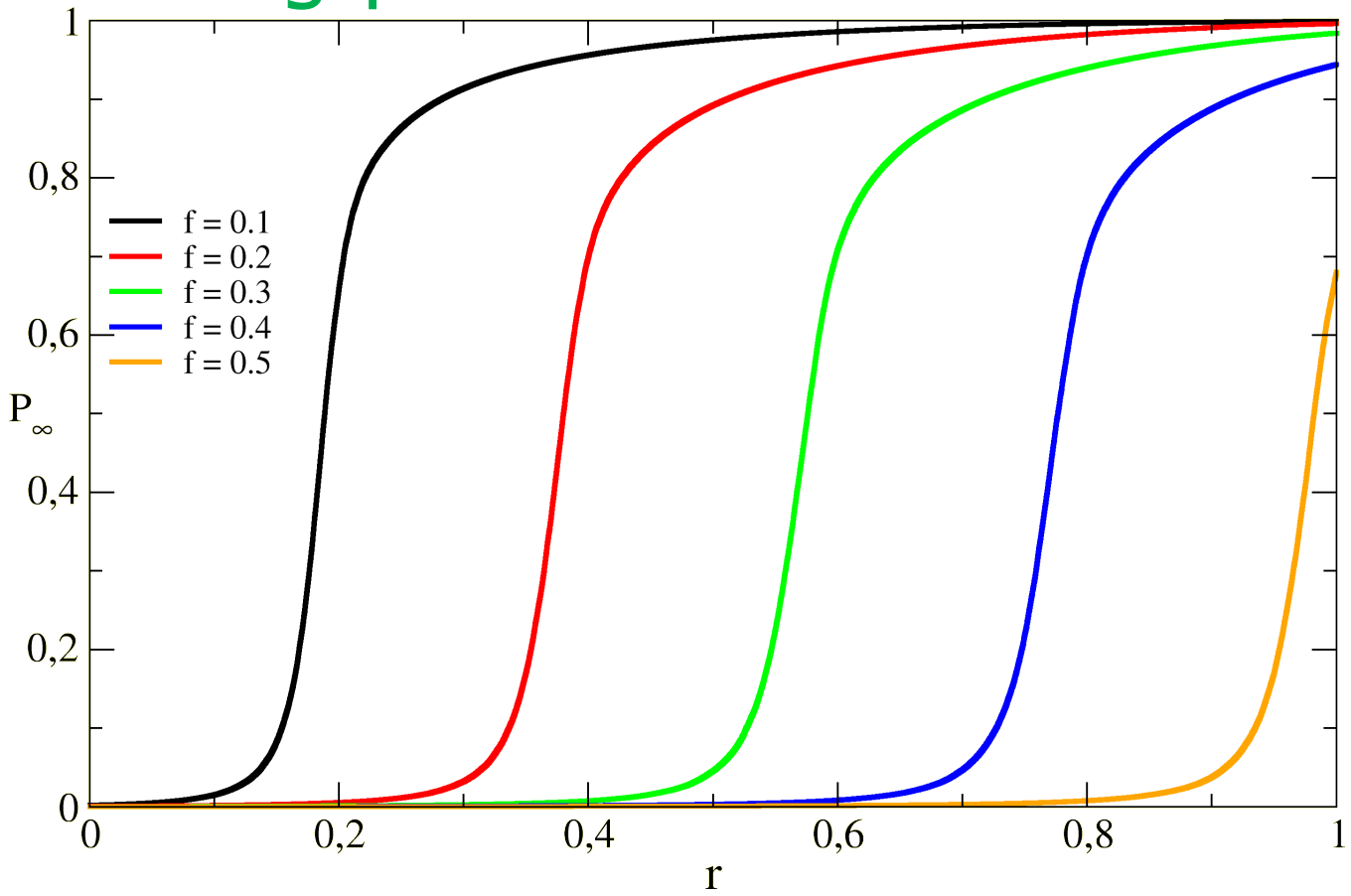
Spanning tree



Redundant links

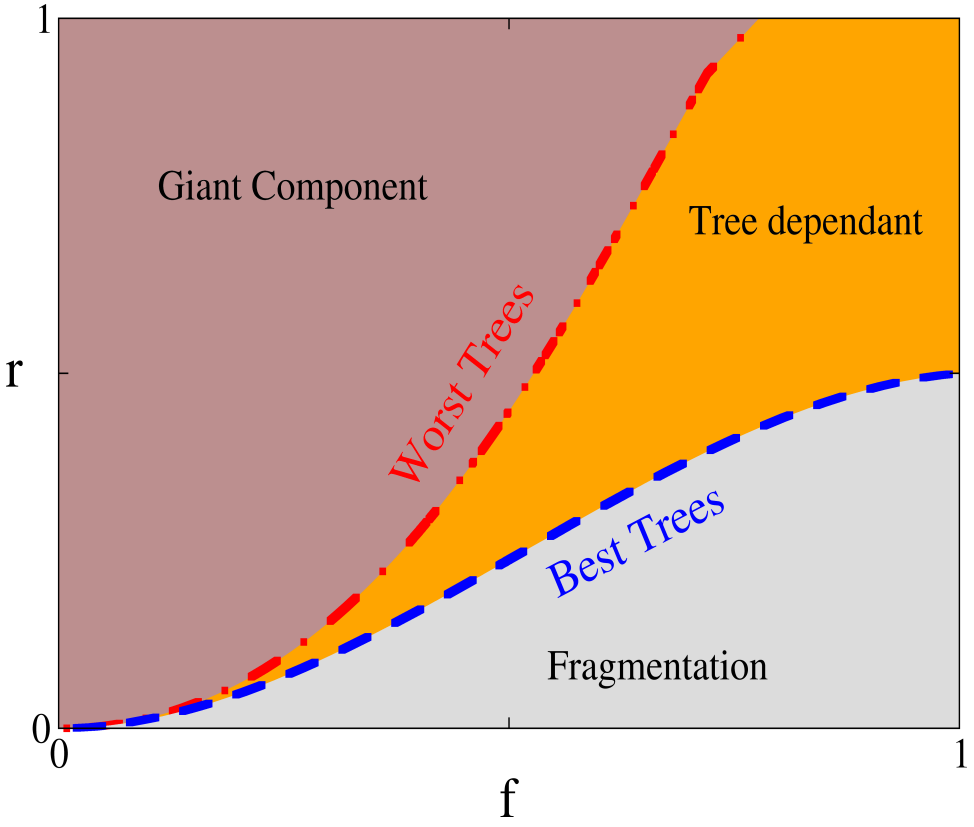
- Failures happen only on the SPANNING TREE
- Percolation = Survived links + redundant links

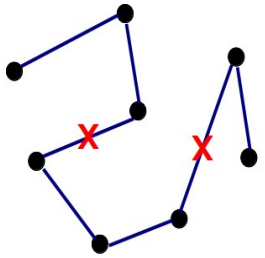
# Self-Healing percolation

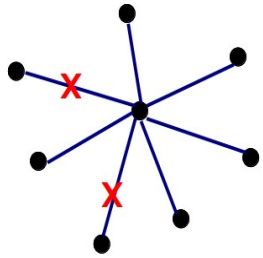


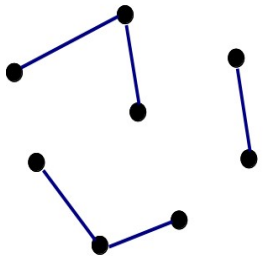

Given the failure of a fraction **f** of links, which fraction **r** of redundant links is needed to keep most of the system connected (existence of a *giant component*) ?

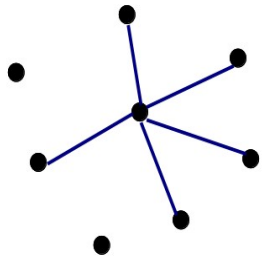
# Topology of the distribution tree





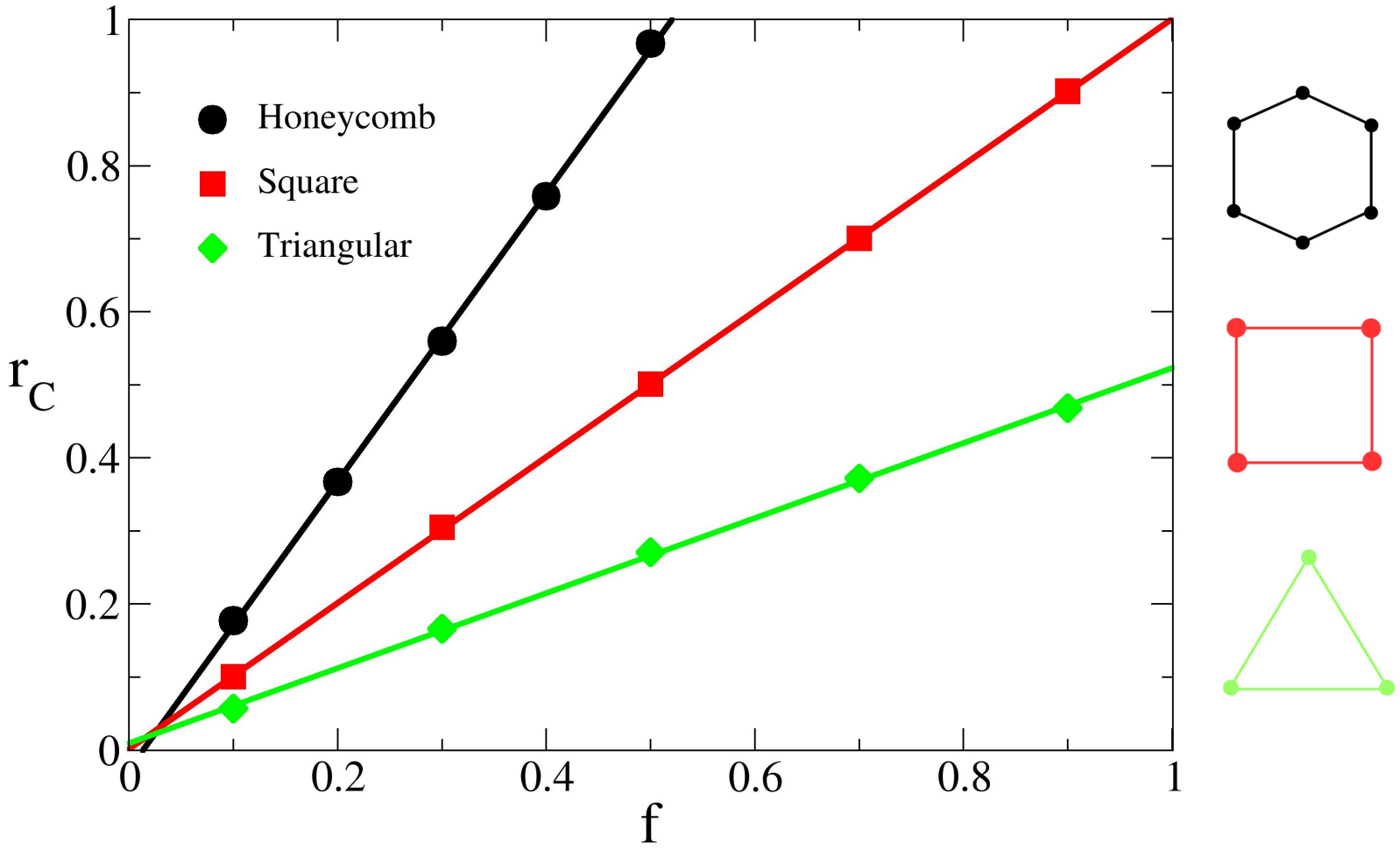


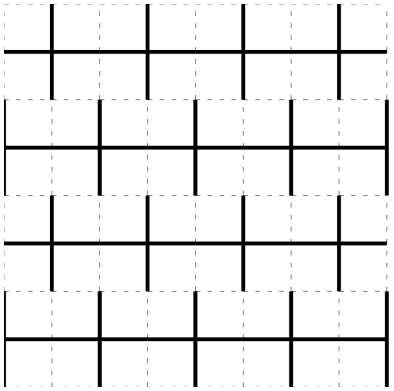

For random nets:

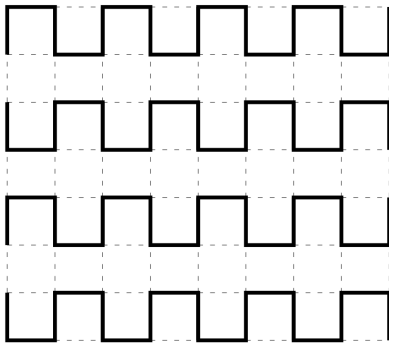
- Chain is the most fragile
- Star is the most robust

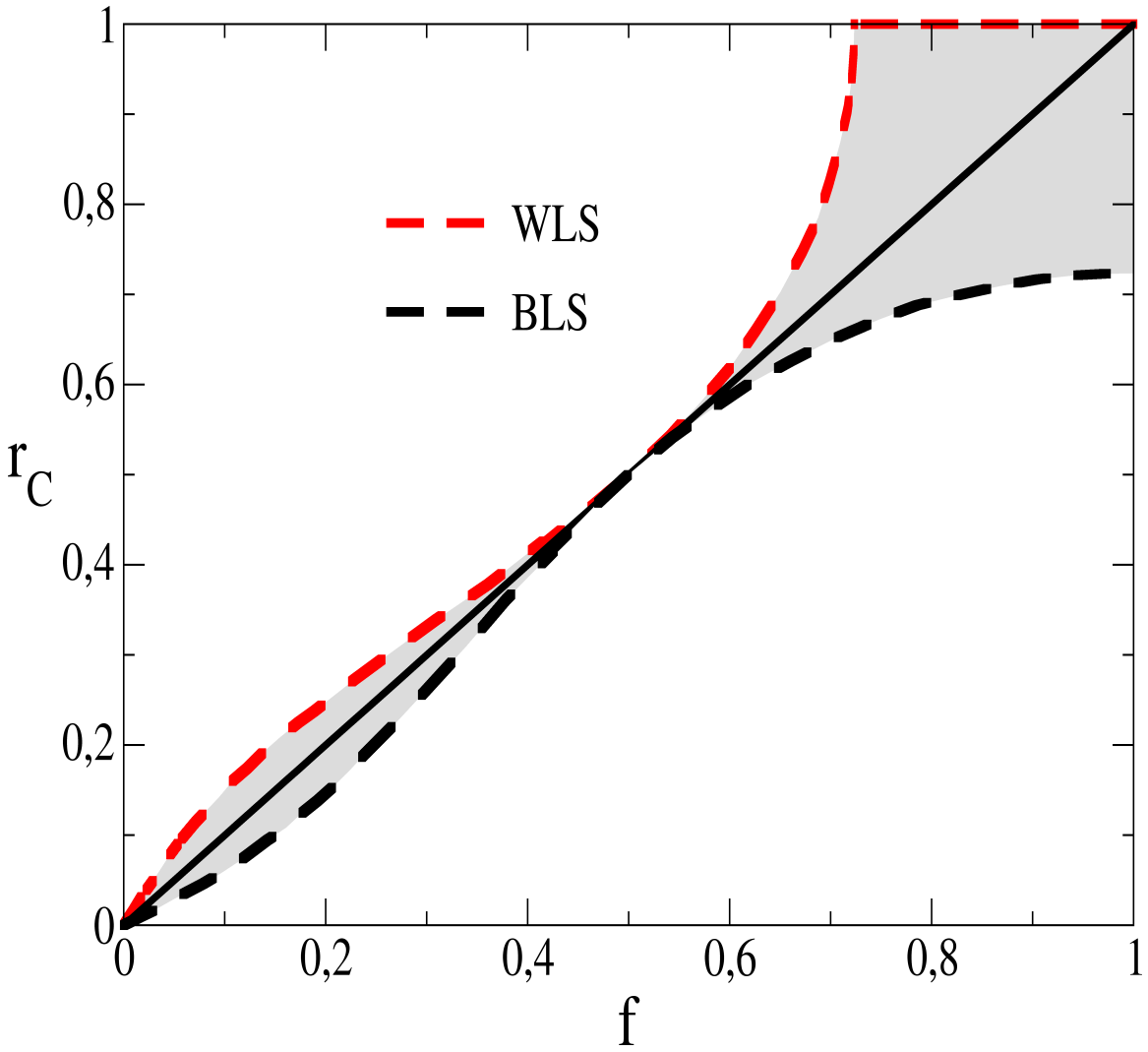
# Self-healing for planar lattices



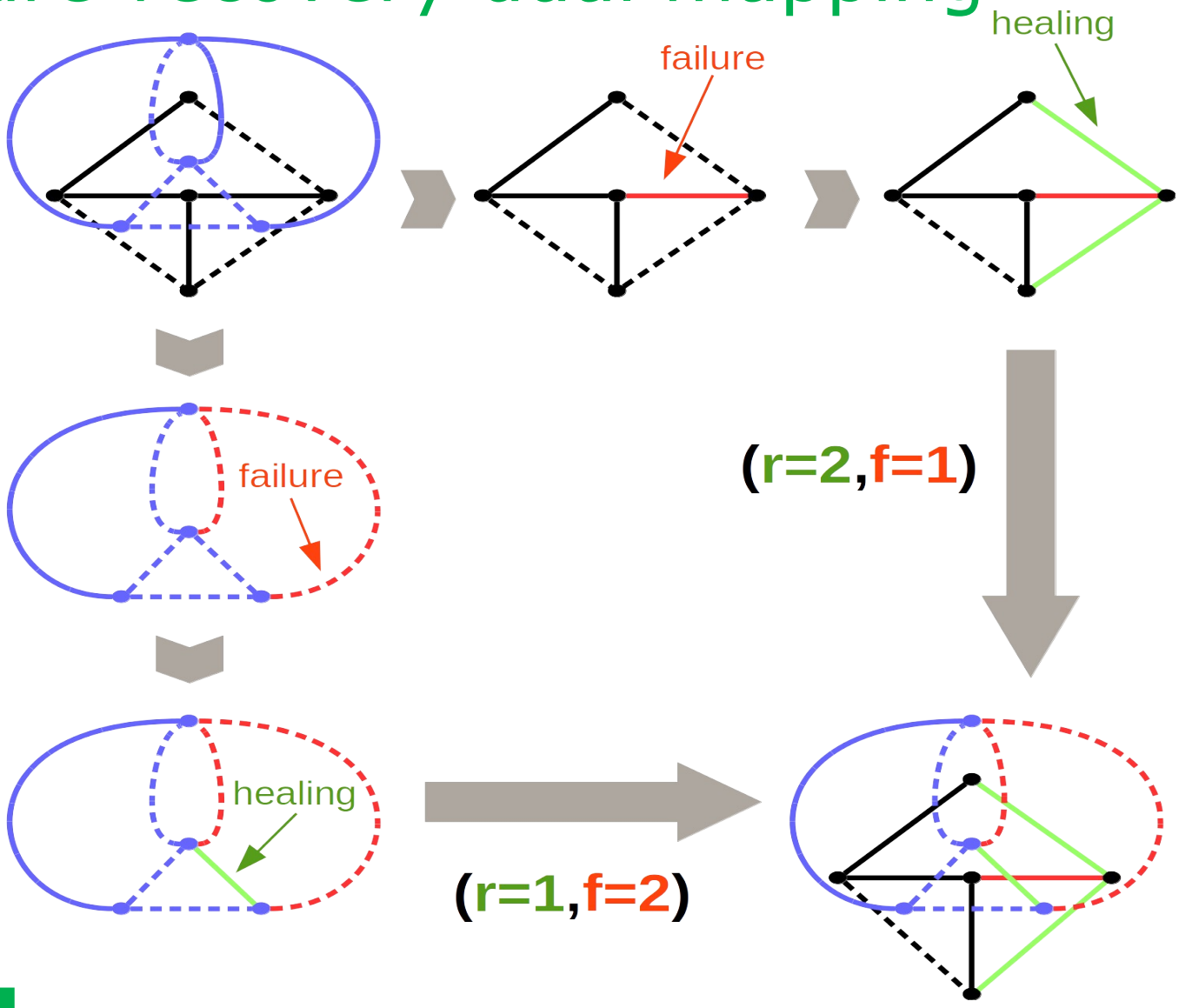
# Optimal trees on SQ lattice



# Failure-recovery dual mapping



# Conclusions

- distribution networks have often built-in redundancies; "smartness" can be introduced and accomplished customizing "on the market" routing protocols

***smartness = stat-mech + distributed algorithms ?***

- Self-healing as a message passing problem
- Self-healing as a percolation problem

***much yet to do !!!***

- optimising the topology
- optimising the redundancies
- considering fluxes
- multiple/competing sources

THANKS TO:

- CNR-PNR National Project Crisis-Lab
- EU FP7 IP nr.317532 MULTIPLEX - Foundational Research on MULTIlevel comPLEX networks and systems
- EU HOME/CIPS project CI2C "Critical Infrastructures and Cloud Computing: understanding cross-sectorial criticalities and security practices"
- EU FP7 project DOLFINS "Distributed Global Financial Systems for Society"