Finding the best immunization strategy

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Motivation to study immunization strategy

With random vaccination, to stop the spreading of diseases or computer virus in human society or computer networks, the fraction of population need to be vaccinated can be very high.

- **Infectious disease**
- Malaria 99%
- Measles 90-95%
- Whooping cough 90-95%
- Fifths disease 90-95%
- Chicken pox 85-90%
- Mumps 85-90%
- Rubella 82-87%
- Poliomyelitis 82-87%
- Diphtheria 82-87%
- Scarlet fever 82-87%

INTERNET 99%

Vespignani, Pastor-Satoral, PRL (2000), PRE (2001)

Previous studies

Many scientists took part into the modeling of immunization strategies on complex networks and several immunization strategies were developed. For examples:

- acquaintance immunization[1]
- targeted immunization[2]

[1] R. Cohen et al., Phys. Rev. Lett. 91,247901 (2003)
[2] P. Holme et al., Phys. Rev. E 65, 056109 (2002)

Definition of the Best immunization strategy

- To immunize a network system, such as a population, or a computer network like the Internet, with a minimal number of immunization doses.

Equivalently to say:

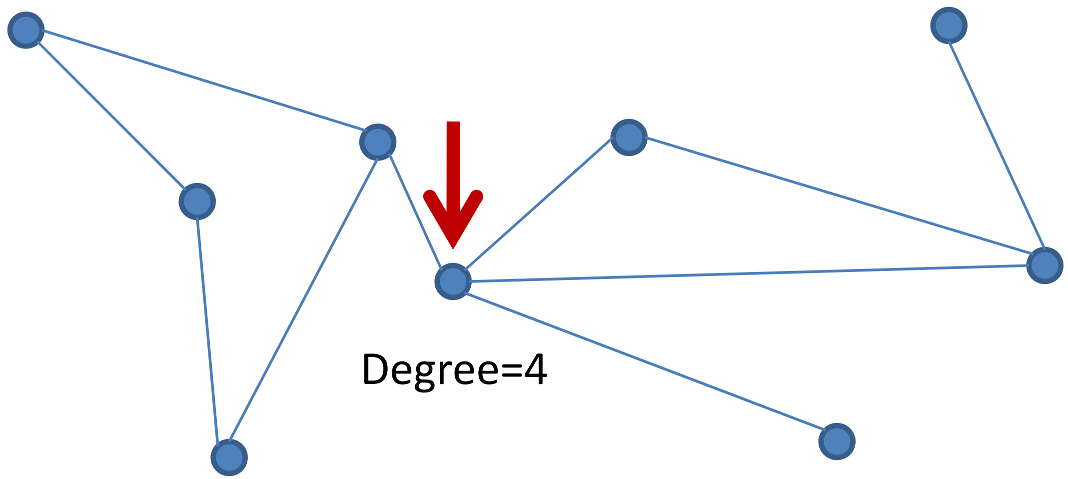
- To fragment a given network with a minimum number of node removals.

The most efficient known immunization strategy

“targeted” strategies:

immunizing the nodes with highest importance,

i.e. Degree or Betweenness.



This is widely believed the most effective immunization strategy, especially for scale-free networks.

Our work

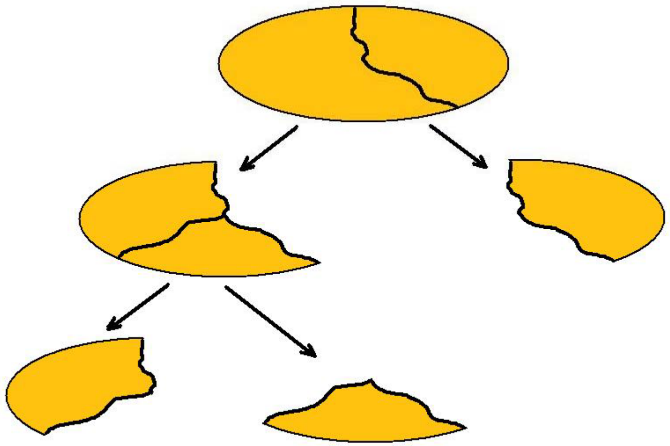
We propose a novel immunization strategy :

Graph Partitioning (GP) strategy

This strategy is based on Nested-Dissection (ND) Algorithm
(developed for sparse matrices filling reduction)

Advantage of GP strategy

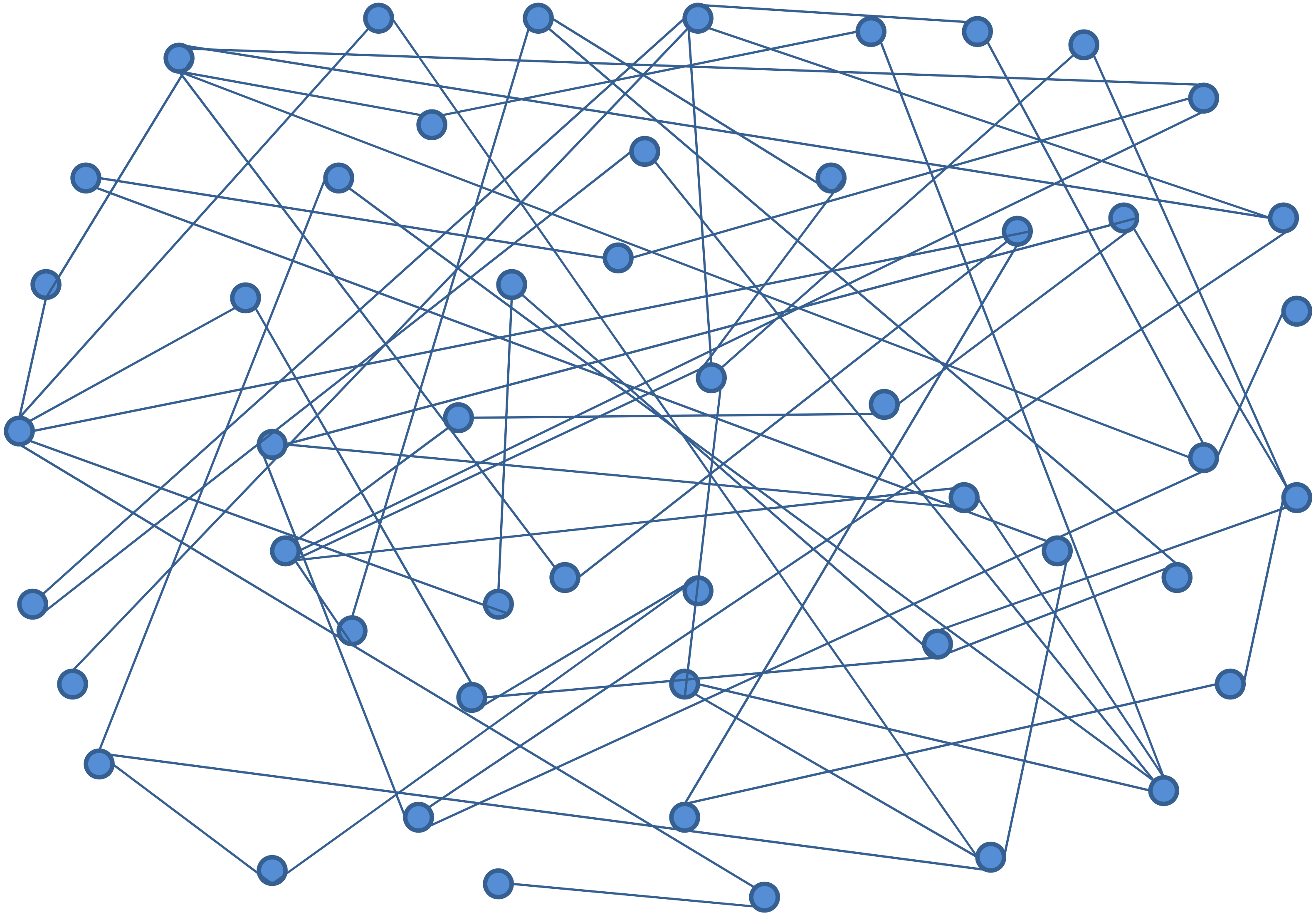
This strategy can partition a network into arbitrary number of same size clusters.



All clusters will have the same size. Thus it will save a lot of cuts in small clusters than targeted strategy.

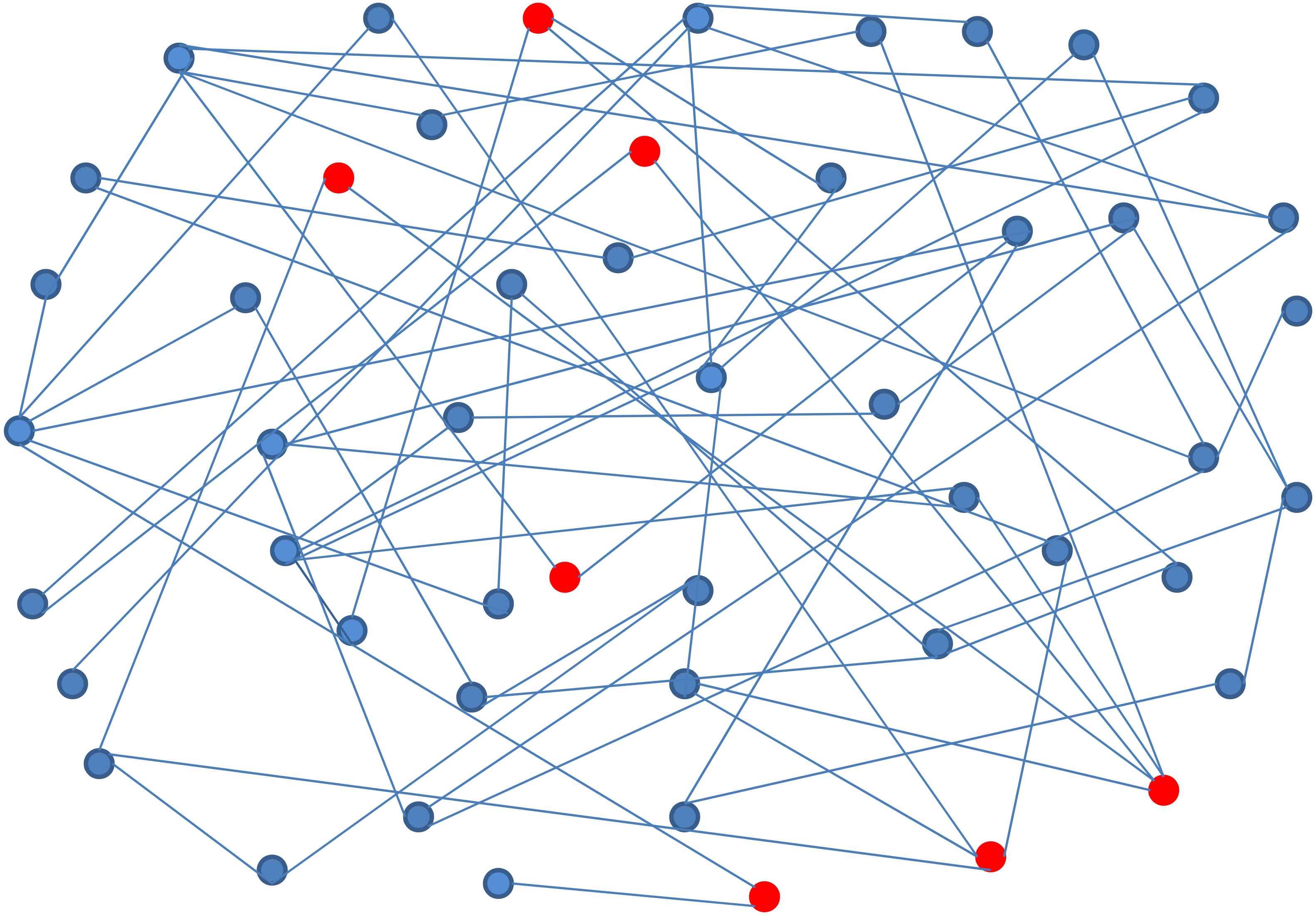
The following slides show an example on one realization of scale-free network.

Random scale-free network N=50 λ=2.5



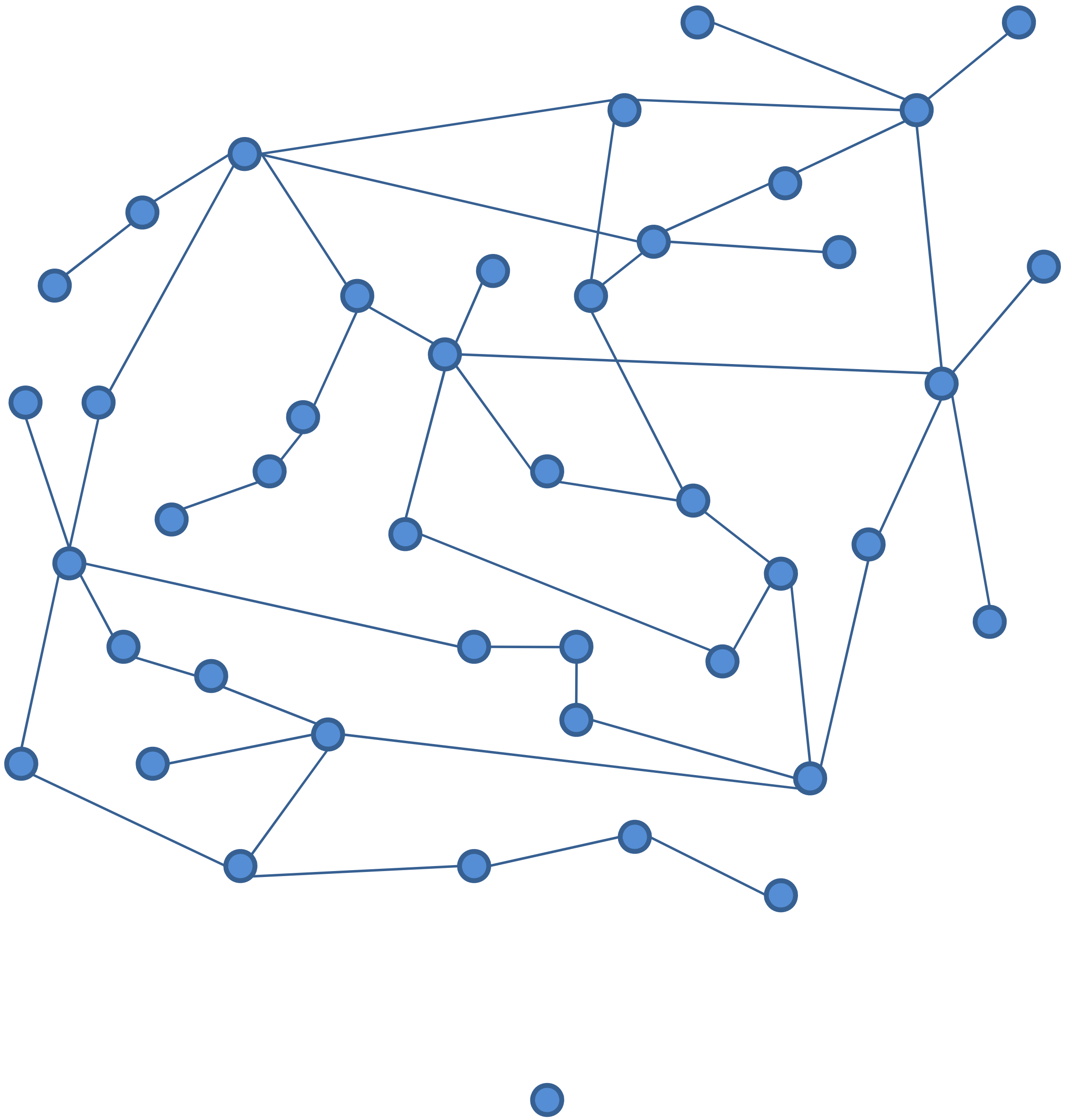
Our budget expects to immunize 7 nodes

Nodes targeted by random (red)



7 nodes randomly selected

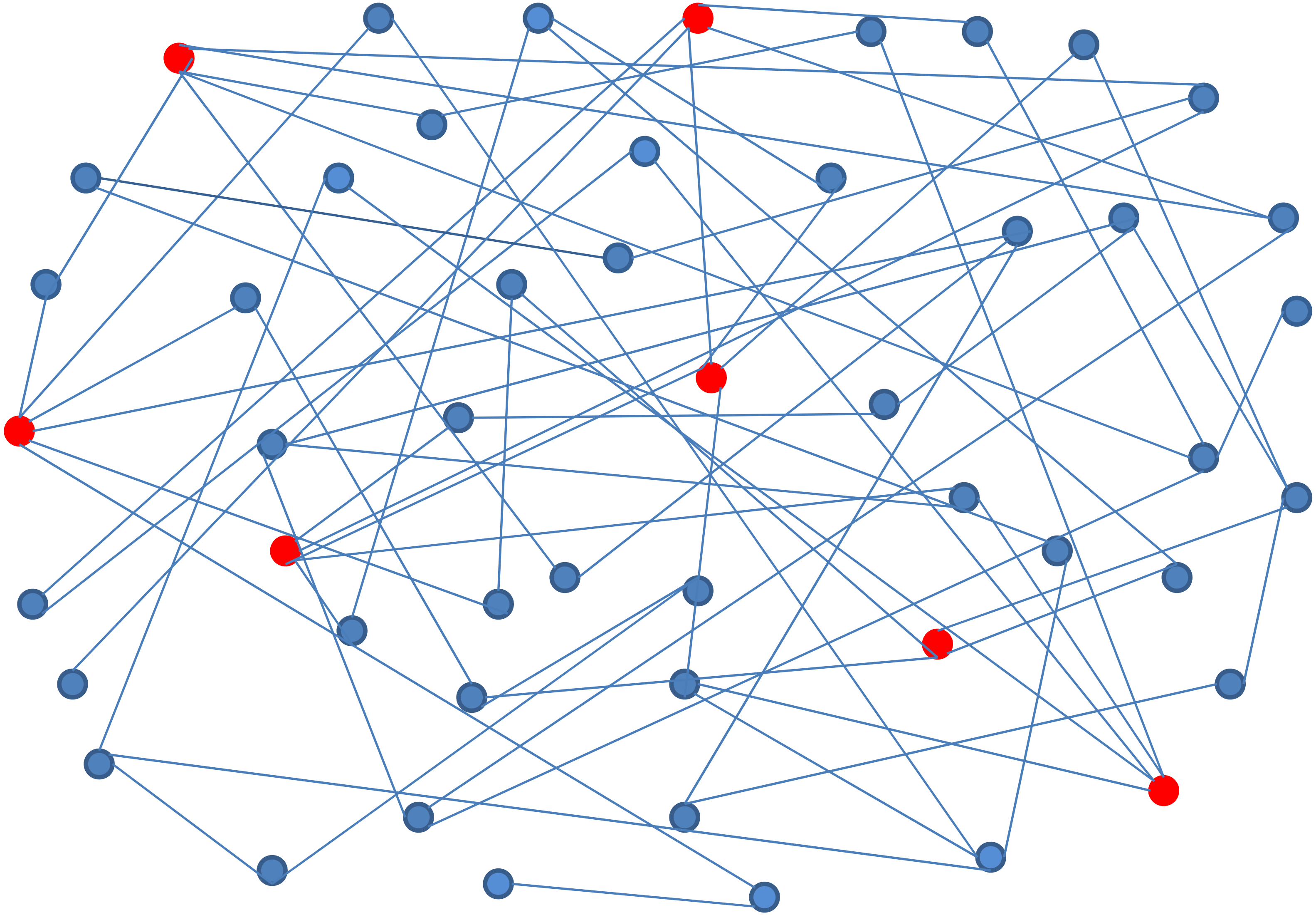
Result after immunization (rearranged clusters)



Size=42
(giant cluster)

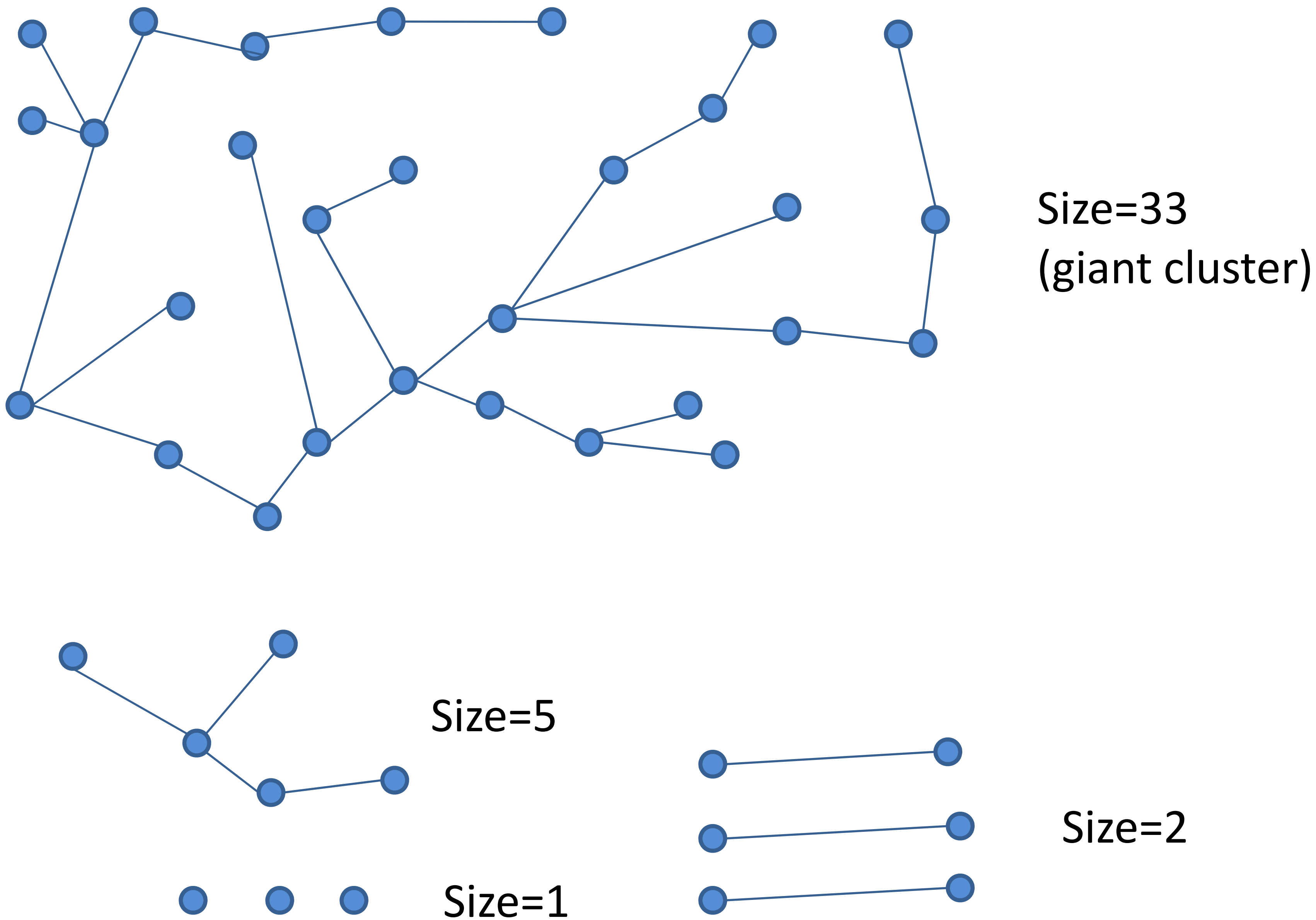
Size=1

Nodes targeted by HD-targeted strategy (red)

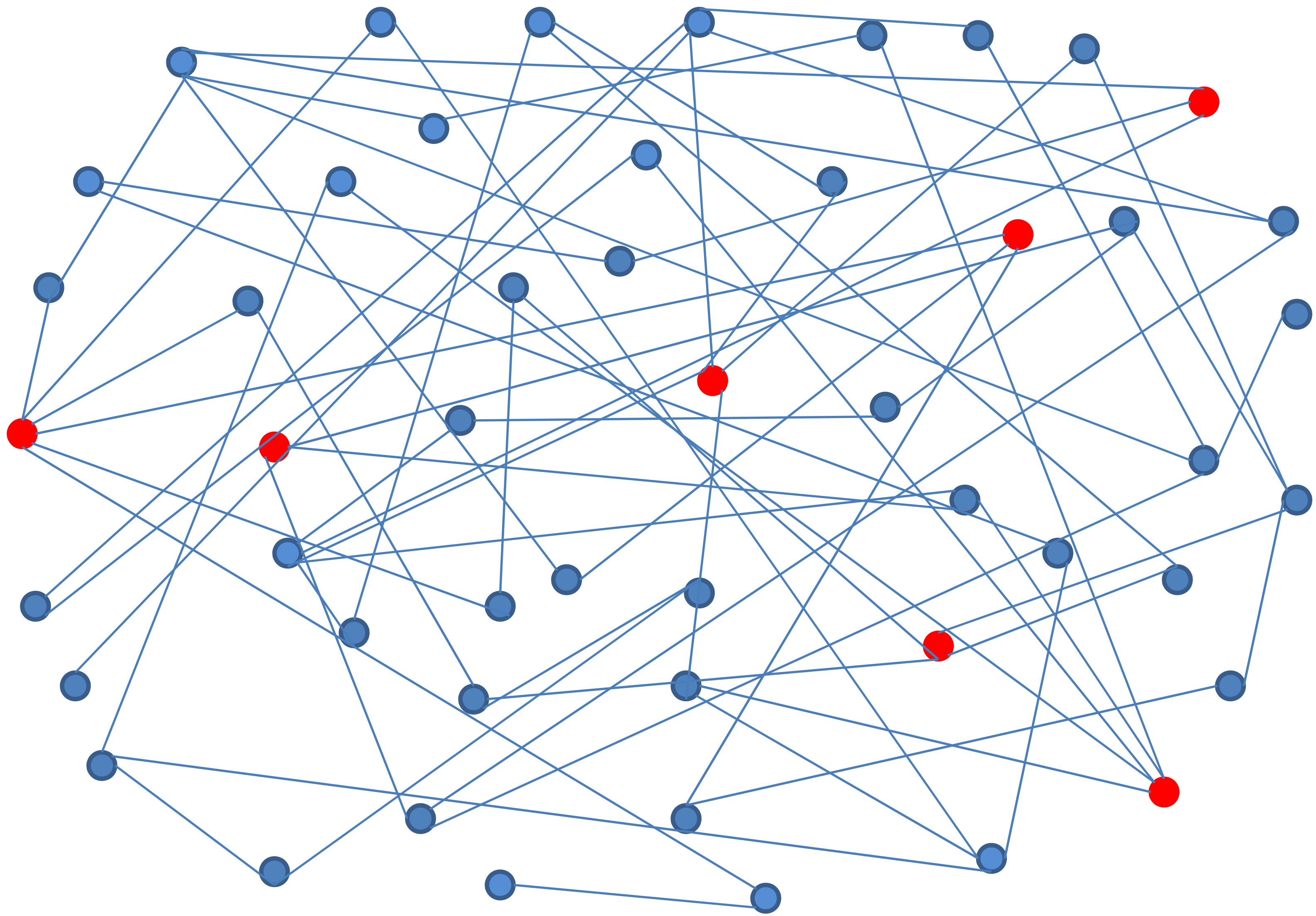


7 nodes with largest degree selected (known most effective)

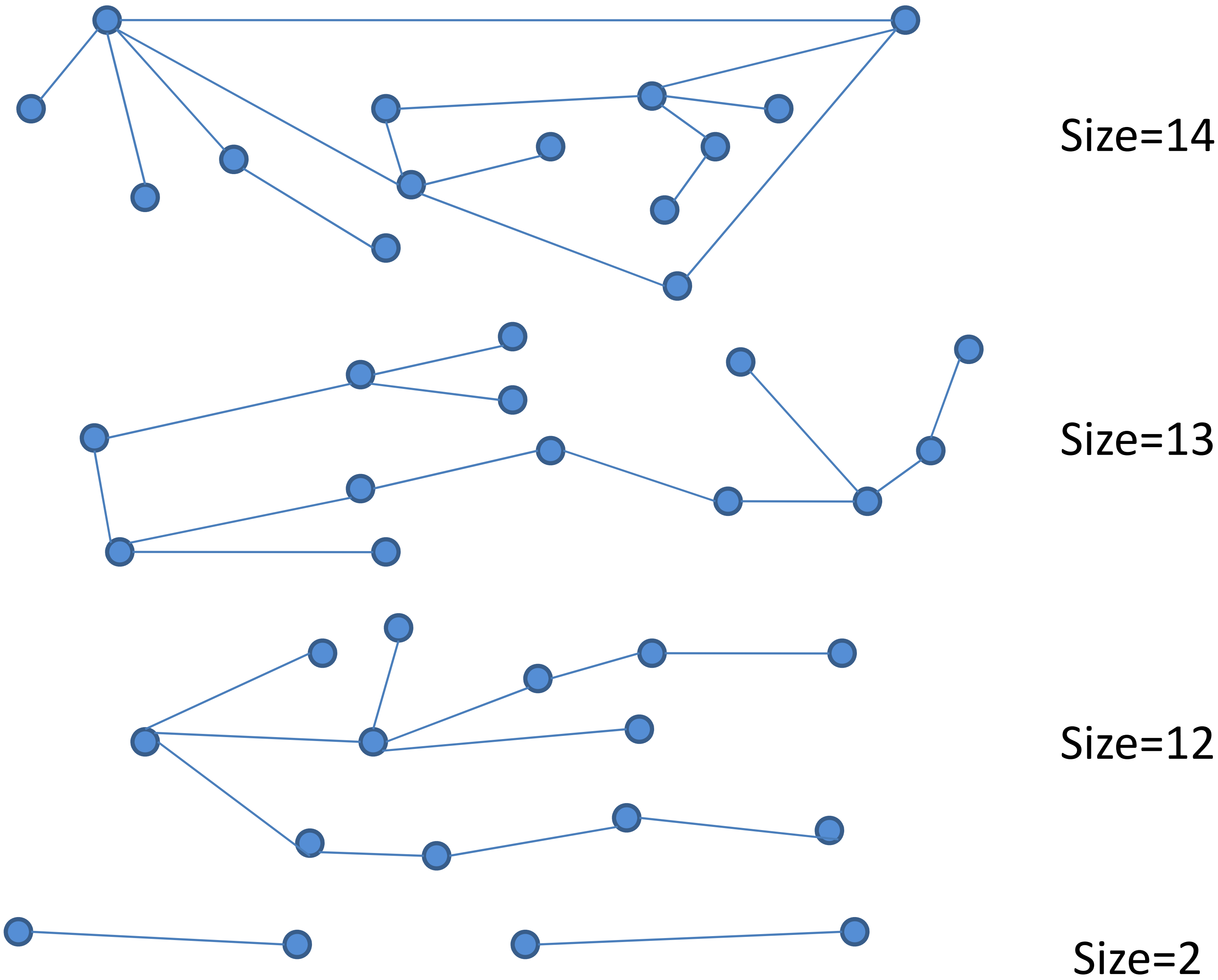
Result after immunization (rearranged clusters)



Nodes targeted by GP algorithm (red)

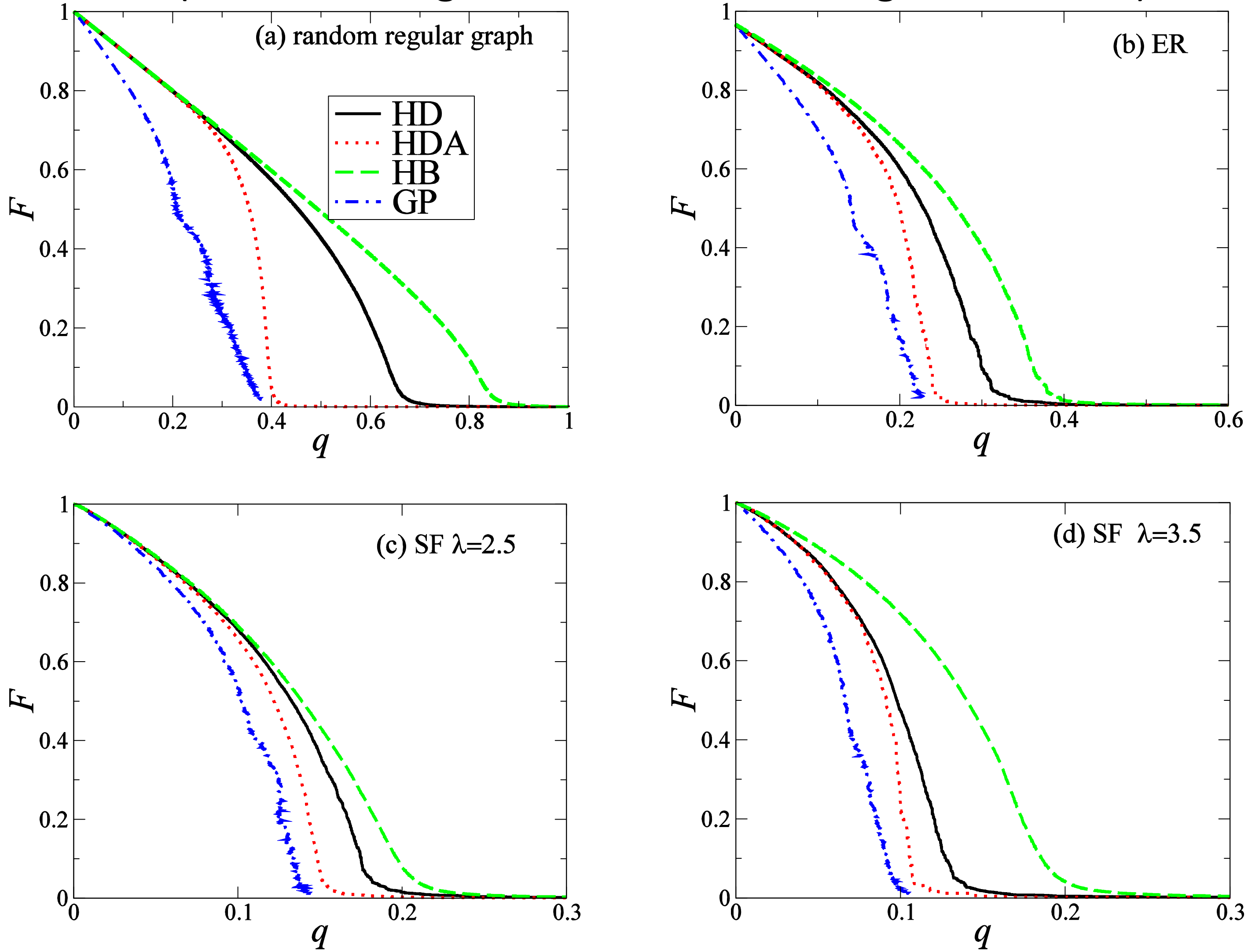


Result after immunization (rearranged clusters)



Immunization effectiveness on model networks

(F = size of largest cluster / size of original network)



HD = high-degree targeted

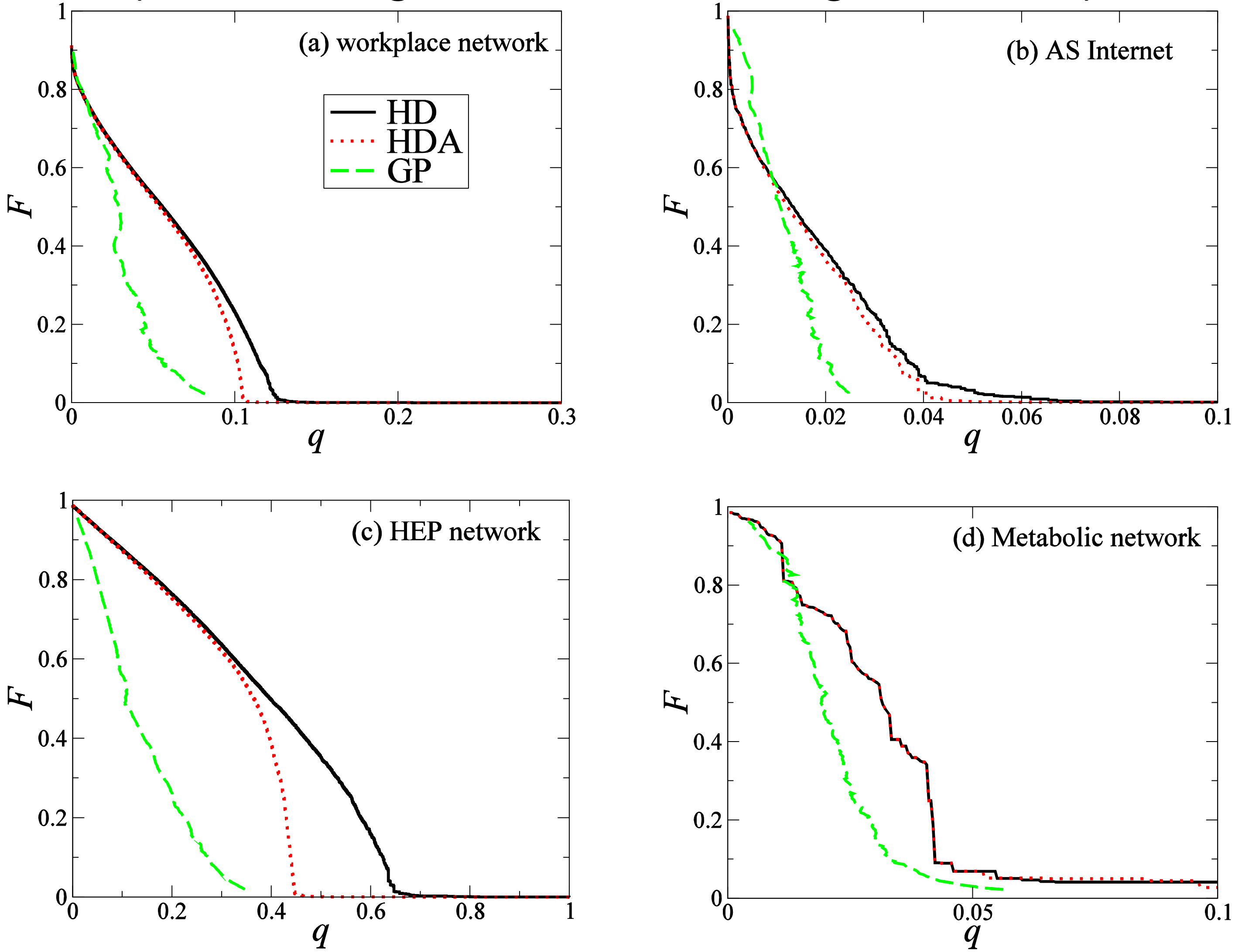
HB = high-betweenness targeted

HDA = high-degree adaptive targeted

GP = Graph partitioning algorithm

Immunization effectiveness on real networks

(F = size of largest cluster / size of original network)



HD = high-degree targeted

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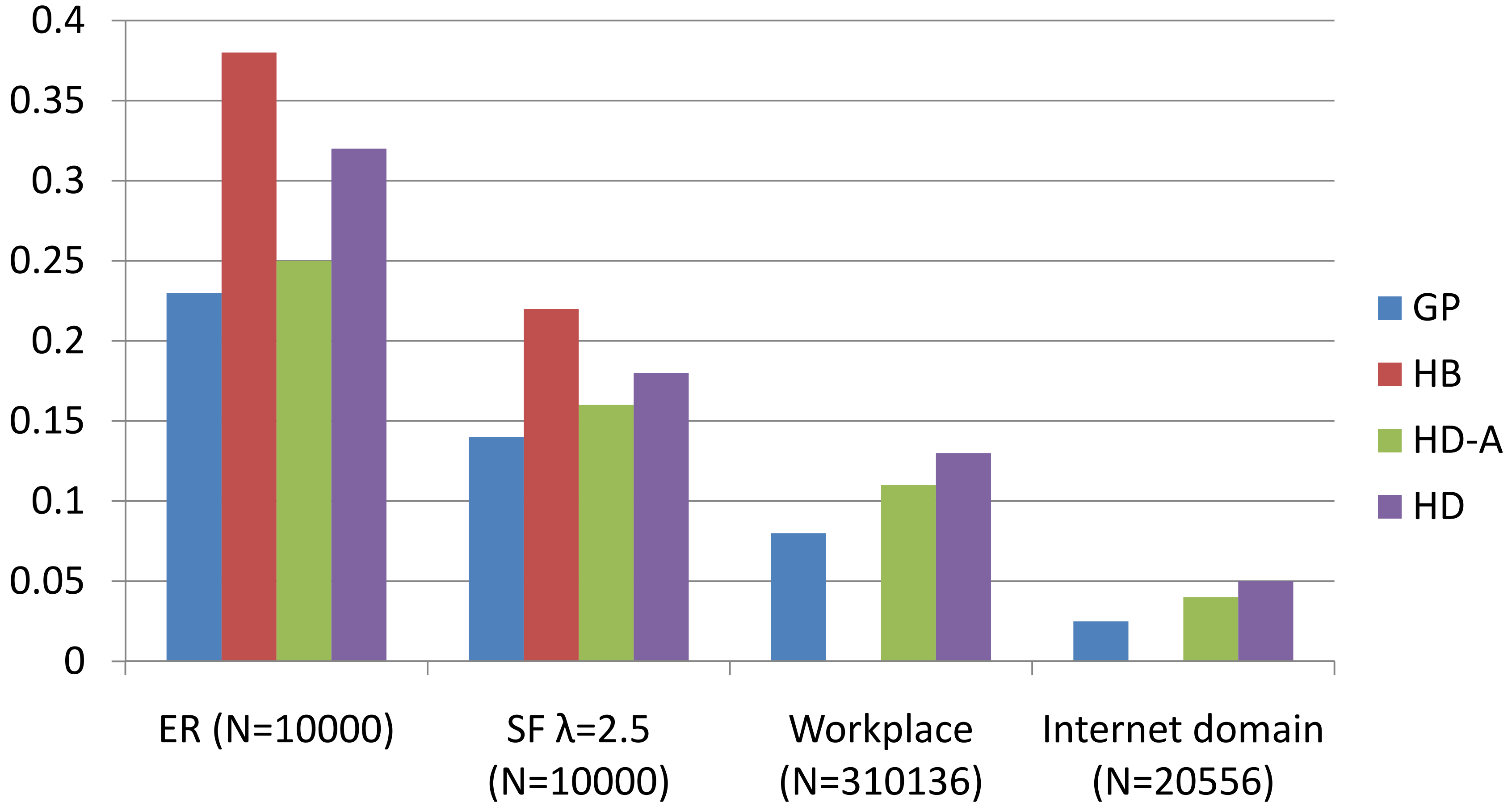
HDA = high-degree adaptive targeted

GP = Graph partitioning algorithm

Ratio of nodes removed when largest cluster size is 2% of total size



Summary

- We propose a novel immunization strategy (GP) significantly better than targeted strategies, with 5% to 50% fewer immunization doses required.