Exploring the Physics of Small Devices
(EPSD)

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Clustered networks and control of the disease spread

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Contents

1 Purpose of the visit

The aim of visiting professor James Gleeson at University of Limerick in Ireland was to study the effect of clustered network on disease spread and on the searching for optimal control scenarios.

Networks modelling has long been used to design strategies to control disease outbreaks. However, in order to design effective strategies for control of disease there is a need for a 'marriage of economics and epidemiology'. In my research both epidemiological and economic factors are of equal importance.

Most studies ignore the spatial components of disease spread and control while searching for an optimum strategy. The spatial scale at which control is applied in relation to the spatial scale of the pathogen dispersal has been identified for many diseases. The relationship between the epidemic and control scales can however be affected by economic aspects of both disease and treatment [3]. Simple network models, while capturing the essence of the topology of spread and control, offer a unique opportunity to analyse the relationship between the epidemic and control scales when there are cost constraints.

Clustering in a complex networks refers to the propensity of two neighbours of a given node to also be neighbours of each other, thus forming a triangle of edges within the graph [1]. It has already been shown that clustering affects bond percolation threshold, i. e. presence of fully connected nodes (triangles) increases bond percolation threshold. In epidemiology the bond percolation has an application as it is related to the spread of a disease [1]. The larger bond percolation threshold, the larger epidemic threshold, i.e. the minimum number of cases that need to be observed in order to assert that an epidemic is taking place. Thus, clustering in the networks increases epidemic threshold. Therefore, the study how clustering affect the control of the disease is essential to design most optimal control scenarios.

2 Description of the work carried out during the visit

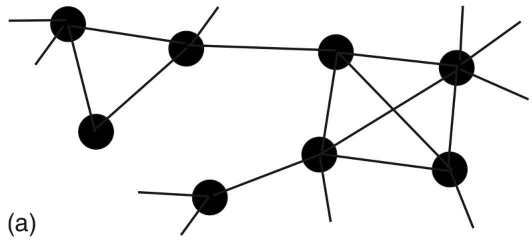

Figure 1: Clustered random networks with 3-clique, 4-clique and a single node [2].

During my visit at University of Limerick I was provided the code in Matlab that generates the clustered networks [2]. Then I have developed and adopted it to my simulations of epidemic spread and control. I have used extended Matlab programs to not only generate clustered random networks but also to find neighbourhood for each node in networks. Neighbourhood of order z=1 to maximal path length in graph is necessary for searching the most optima control strategy [3] for which the epidemic can be stopped at the manageable costs.

3 Description of the main results obtained

The preliminary results have shown that two different behaviour can be observed, for non-invading and very contagion disease. When the disease spreads slowly the most cost-effective strategy is to control the whole population (Global Strategy, [3] if only costs of treatment is smaller that infection costs. Otherwise, the most optimal scenario is to refrain from treatment (Null Strategy). Such a sharp change has been previously observed for random but not clustered networks [3].

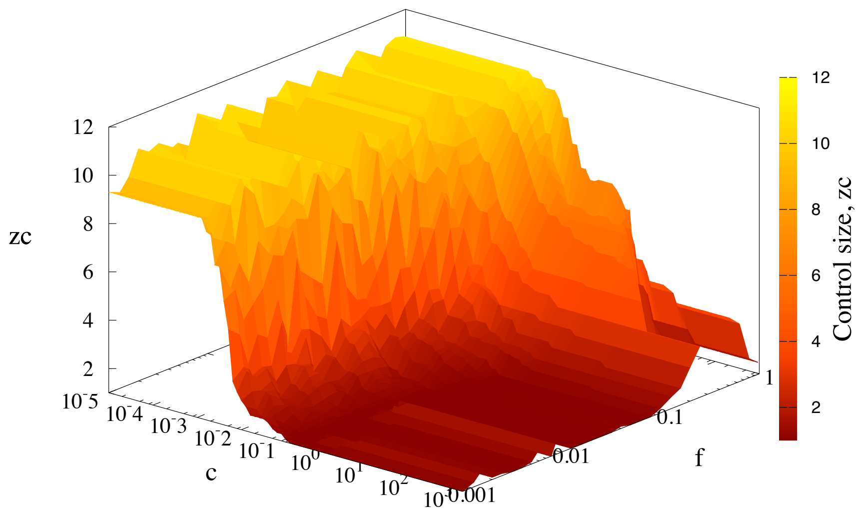

Figure 2:

However, the very interesting region in fig.2 is the area for fast spreading disease. The plateaux denotes Local Strategy, which is the most optimal choice for a wide range of costs. Moreover, LS matches the scale of control to the scale of dispersal [4].

Described results illustrate optimal choice of control for a network with only 1000 nodes. Further works carried on much large systems with up to 20'000 nodes, however such a computing is very time and memory consuming.

4 Future collaboration with host institution

The research has been continued for a larger systems as well as clustered random networks with different properties (described by the joint probability distribution $\gamma(k, c)$ [2]. Subsequently, further discution and collaboration with professor James Gleeson is very appreciated for me.

5 Projected publications / articles resulting or to result from the grant

The work carried out during my visit at University of Limerick was the initial stage of the project. After further research I hope to collect appropriate data for a publication.

References

[1] Gleeson, J., Melnik, S., and Hackett, A. How clustering affects the bond percolation threshold in complex networks. *Physical Review E 81*, 6 (2010), 066114.

[2] Gleeson, J. P. Bond percolation on a class of clustered random networks. *Phys. Rev. E 80* (Sep 2009), 036107.

[3] Kleczkowski, A., Oleś, K., Gudowska-Nowak, E., and Gilligan, C. A. Searching for the most cost-effective strategy for controlling epidemics spreading on regular and small-world networks. *Journal of The Royal Society Interface 9*, 66 (2012), 158–169.

[4] Oleś, K., Gudowska-Nowak, E., and Kleczkowski, A. Understand disease control: influence of epidemiological and economic factors. *submitted to PLoS One*.