Phase transitions in information spreading on structured populations

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Conventional information contagion models (eg-SIR model in epidemiology) usually assume a well-mixed population (mean-field approximation) where everyone individual can interact with every other individual. In other words, these conventional models are unrealistic in the sense that real-world interaction between individuals isn't well mixed but can be thought to take place on an underlying network.

This work studies the diffusion of information (rumor) using the Maki Thompson Rumor (MTR) model on two types of underlying network topology -

1. Metapopulation network
    a. This is a spatial network where nodes represent the subpopulation (eg - individuals of one state/country) and edges represent the mobility between these subpopulations (movement, say air travel, between countries or states)
    b. The parameters (apart from the number of communities and size of each community)
        i. The mobility (weights of edges) - p
        ii. Degree of a subpopulation - k
2. Modular Activity driven (MAD) network
    a. This is a non-spatial network evolving with time (in a markovian way - at each time step the existing edges (network) is deleted (forgotten) and new edges are formed) where individuals are confined to a single community (unlike metapopulation network where they can move between communities), but when activated choose to form links to those outside their current community based on a probability of inter-community interaction.
    b. The parameters (apart from the number of communities and size of each community)
        i. The activity rate of individuals - a
        ii. Probability of inter-community links forming - μ

Categories of individuals in MTR model -

1. Ignorants - those who do not know the rumor.
2. Spreaders - those who know and are actively sharing the rumor;
3. Stiflers - those who know the rumor but are no longer spreading it.

The contagion process evolves through interactions between individuals in a population. Parameters -

1. λ - the rate of spreader transforming ignorant into a spreader.
2. α - the rate of the spreader transitioning into a stifler upon meeting a stifler or spreader.

MTR on well-mixed population does not exhibit a rumor spreading threshold. However, the work of this paper shows that introducing a network topology as above, makes it exhibit a spreading threshold.

Reflection -

1. I liked the fact that this was also tested on synthetic networks with a heavy-tailed (in this case, power-law) degree distribution. The reason being, the existence of super-spreaders, in the context of epidemiology, has shown to exhibit some non-trivial behavior (loosely, there can be a finite fraction of infected individuals even if R_0 is less than 1)[1]

2. Although it has been loosely discussed in the supplementary section, it surprises me that equation 6 and/or 7 is independent of the activity rate 'a'. I currently cannot comprehend the meaning of this right away and would need to dig deeper into some of the math. However, given that 'a' governs

[1] http://www.ffn.ub.es/albert/complex_networks/romu.prl.pdf

which of the individuals are connected (via edges) in MAD and thus participate in the contagion, doesn't it seem weird that the critical threshold point does not depend on this?

3. The empirical analysis does indeed validated the existence of a critical threshold point (CTP) which is not an artifact of the MTR model on well mixed popialtuon. In this sense, the result of the authors is novel. However, while empirically validating the existence CTP, the authors skip checking the CTP obtained with that derived from equations 4 and 7. They admit that heterogeneity within populations and a correlated network structure might be needed for an exact match. How did they come up with this speculation? If the analytical CTP doesn't match what is found empricially, rather than specualting that additional complexity needs to be introduced to the model, what frees the authors from question whether their existing model is accurate in the first place?

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