Epidemic Control

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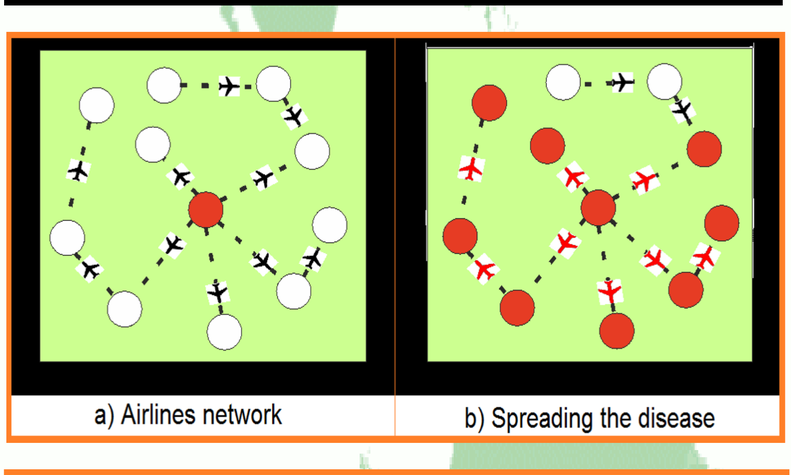
Introduction

Study of Spreading of disease through travel network has recently become one of the important research topic. Airplane network is most crucial among them as they can quickly propagate the disease around the world. This simulation tests various strategies to slow down the propagation of disease. The SEIR model is used to simulate the infection across airline network. This simulation test five different flight cancellation strategies to limit the spread of infection. The number of infected airports after applying these cancellation strategies is used as a parameter to rank the strategies.

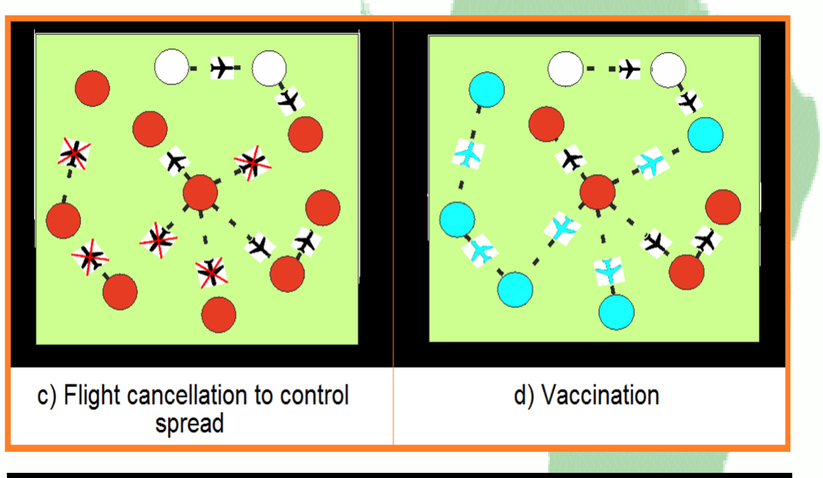
Data Set

This simulator runs on openflights airline network data. The network has 6977 airports and 67663 flights. Airports are nodes of the network and flights are edges. The network is a small-world network characterized by a power-law decaying degree distribution

Method



a) Airlines network | b) Spreading the disease



c) Flight cancellation to control spread | d) Vaccination

Spreading

The high degree randomly chosen nodes are used as a starting node to propagate the Infection. The process runs for hundred days

Cancellation

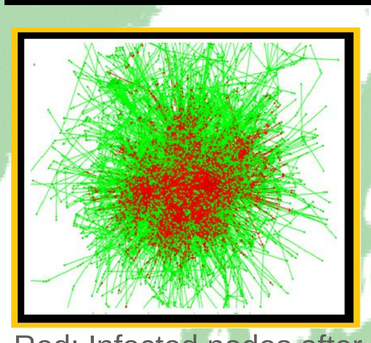
Betweenness centrality is used to find the candidate edges for removal which are all pair shortest path crossing each nodes. Removal of these edges will increase the average number of steps for spreading.

Jaccard Coefficient is used to compute neighborhood similarity structure of two nodes, dissimilar nodes can represent a shortcut between remote regions.

Clustering coefficient is used to find cluster in the graph. The nodes with low clustering coefficient means they are loosely coupled within the network and have weak ties.

Hub Identification is used to identify high degree nodes, removal of these nodes will restrict spreading of infection.

Betweenness

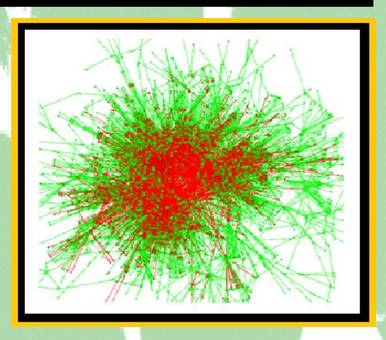


Red: Infected nodes after removing 25% of high betweenness edges

In betweenness strategy, the nodes in the center are more infected than the one on periphery, so the rate of infection is lower for those airports who are far from the central nodes. The population of red nodes are less dense than the one from clustering coefficient, when only 25% of edges are removed.

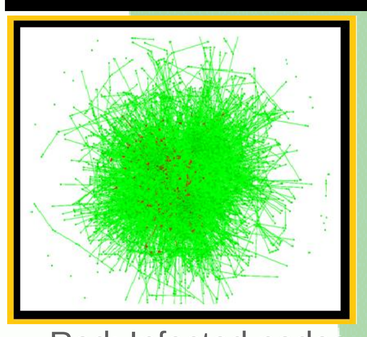
Clustering

In clustering coefficient strategy, the population of red nodes are denser than the one from betweenness strategies, however when more than 40 % edges are removed, the result is opposite when compared with betweenness strategy.



Red: Infected nodes after removing 25% of edges connecting low clustering coefficient

Hub Removal

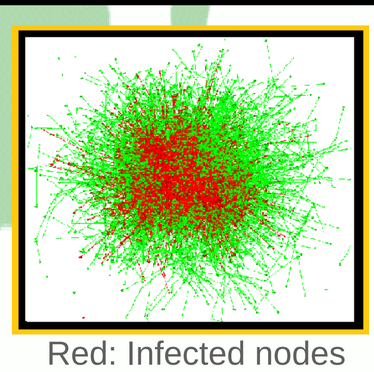


Red: Infected nodes after removing 10% of nodes

This is the best strategy where high degree nodes are removed and limiting the propagation to very few nodes but shutting down the major HUB (larger airport) is very expensive for humans.

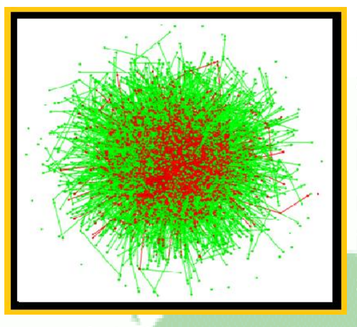
Jaccard

In jaccard Coefficient strategies, the count of infected nodes is not less than the other strategies but the infected nodes are more scattered even the infection reaches to few peripheral nodes.



Red: Infected nodes after removing 25% of edges low jaccard coefficient

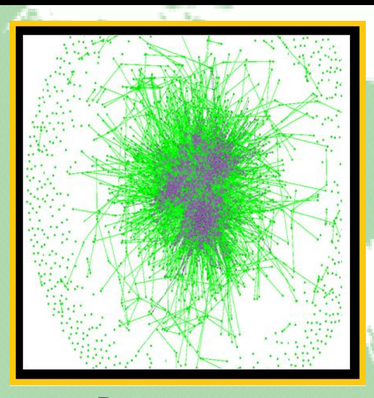
Random



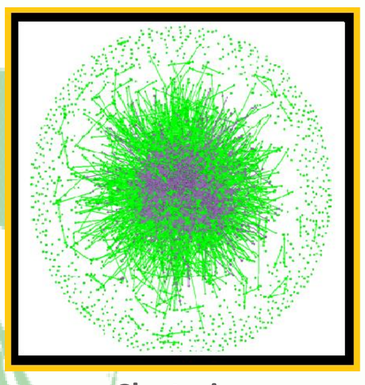
Red: Infected nodes after removing 25% of random edges

Random edge removal where any edge is randomly removed from the network here the count of infected nodes is also high and the infected nodes are also scattered. The infection reaches to peripheral nodes.

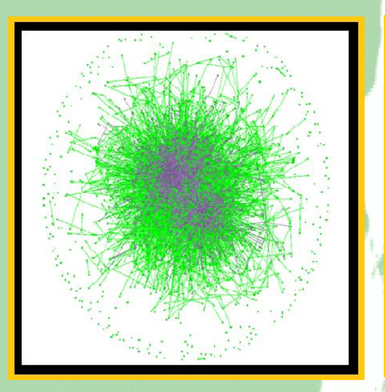
Vaccination



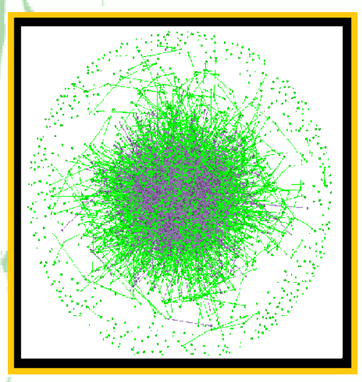
Betweenness



Clustering



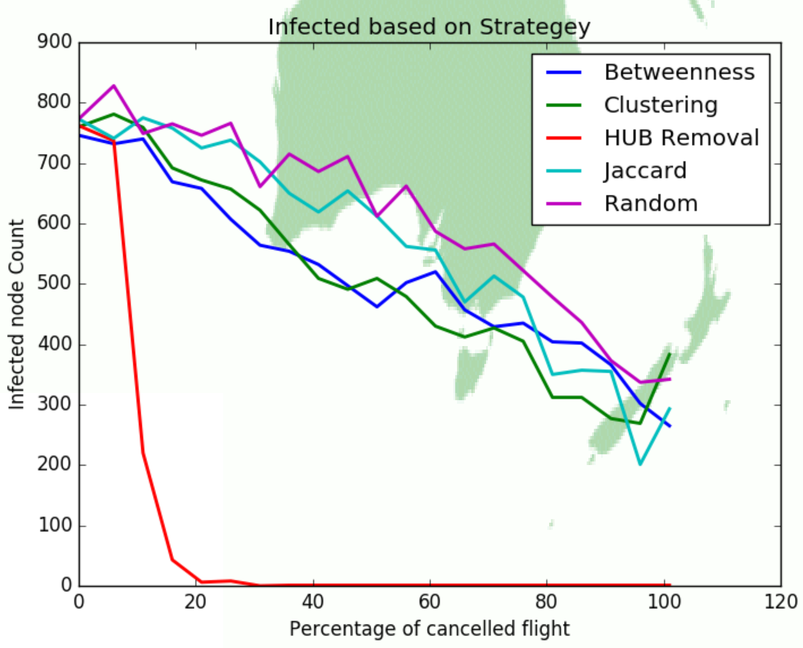
Random



Jaccard

Comparison

The below line graph explains that the Hub Removal strategy result in least number of infected airports which can be predicted because since the hub itself is removed the propagation channel is closed and this limit the propagation of infection. With just 30% cancellation of flight betweenness comes out to be more efficient than the clustering coefficient and jaccard coefficient. With more than 40% cancellation of flight clustering coefficient comes out to be more efficient than jaccard coefficient and betweenness. The random edge removal strategies comes out to be more expensive as the count of infected nodes are high throughout the simulation also the infection is uniform throughout the network and reaches at the peripheral as well. Although in some simulation test, random edge removal strategy displayed moderate result.



Conclusions

The flight cancellation effectively limits the propagation of infection. We suggest that control group should chose the strategy intelligently after considering all parameters i.e. if the disease is severe and the number of days after first exposure is more then Hub removal can be good candidate algorithm. If the results are needed from the moderate number of flight cancellation then betweenness is good.