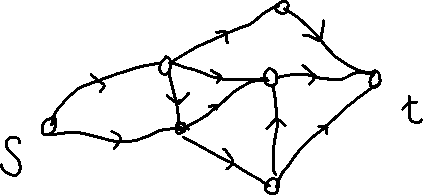
# Using a CTMC model with GCN for predicting path probabilities in a smuggler network

**Assumptions:**Consider the above graph G, with nodes, and an adjacency matrix . Each of the nodes, are assumed to have an associated set of features of length , captured in the matrix . Similarly, each edge has some features, expressed in the matrix , where is the number of edges. Our aim is to predict the probabilities of paths taken by the smugglers, for a given defender coverage strategy. So, we assume that the coverage probabilities are also fixed, and known as a vector: , where for some budget



**CTMC Model assumption:**

The movement of the smugglers can be modelled using a Continuous-Time Markov Chain (CTMC) because at every node, the next step doesn’t depend on the history of the path taken. The idea is to use a GCN/NN to predict the ‘transition rate’, for every edge. The transition rate captures the degree of ease of smuggling goods along an edge. Larger the rate, easier/more favorable it is for the smugglers to smuggle along the edge. For example, two nodes connected by a long flight with multiple stopovers, will have a lower ‘rate of transitioning’ as compared to two nodes connected by a short, direct flight. It is analogous to rate of water flowing in a pipe; a bigger pipe will have a larger rate of water flow while a smaller pipe/choked pipe (read: edge which is difficult to traverse because of checkpoints, obstructions etc.) will have a smaller rate.   
  
**Computations/Algorithm:**

Probability of every path

Compute rate for every path

Effective rate

Predicted rate

NN

Rate prediction for every edge

Processed features

Edge features

Node features

GCN

GCN