Introduction and Back Story

On August 7, 1998 a series of attacks occurred on United States embassies in Tanzania and other East African States causing hundreds of casualties. It was the first time that Osama bin Laden, who was linked to the bombings, was brought to the attention of the American public. Subsequently, bin Laden became one of the ten most wanted fugitives of the FBI.

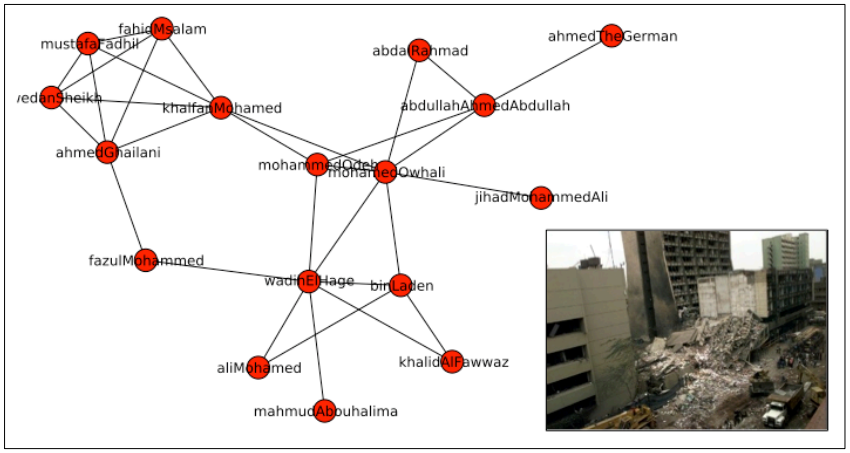

Figure 1: Tanzania Embassy Bombing Network

This project analyzes the social network of bin Laden at this time as seen in figure 1. We assume that we cannot detain bin Laden himself at this time, because he is too well secured and hidden. However, we have good intelligence on his social network and try to disturb this network as much as we can by detaining key players. The objective is to find potential detainees such that we cut off a group as big as possible from communication with Osama bin Laden.

1. Define the Model

In a first step we define a model we can use max-flow on to find the potential detainees. As you can see on the small sample network in figure 2, the original dataset, which is shown on the left, is an undirected graph. Node *X* represents the terrorist leader.

On the contrary, max-flow requires directed graphs. Since communication is bidirectional we replace each undirected arc by two directed arcs – one for each direction. Moreover we interdict this network on its nodes instead of its arcs, which requires an additional modification. We split each node into an incoming and outgoing node with an edge of capacity 1 from incoming to outgoing. We call this new edge split-edge. Interdicting a split-edge is the same as taking the original node out of the network, which means detaining this terrorist. The remaining arcs, representing the ways of communication, have infinite capacity, resulting in not being able to interdict these edges.

The potential detainees can be found by looking for the s-t cut in our new model. Therefore we need to specify a start and an end node. Since we want to disturb the communication outgoing from the terrorist leader, the start node is one of the two *X* nodes. If we choose X_{IN} the s-t cut is always on the edge from X_{IN} to X_{OUT}[1]. Hence we choose X_{OUT}, which also makes sense intuitively since we want to

[1] After the first iteration with one flow the arc between X_{IN} and X_{OUT} changes its direction in the residuals graph. Then there are no outgoing edges on X_{IN}.

interdict communication outgoing from terrorist leader *X*. Similarly, we choose an incoming node for the end node. In order to find the optimal s-t cut for our scenario we let the end node cycle through all incoming nodes and compare the results.

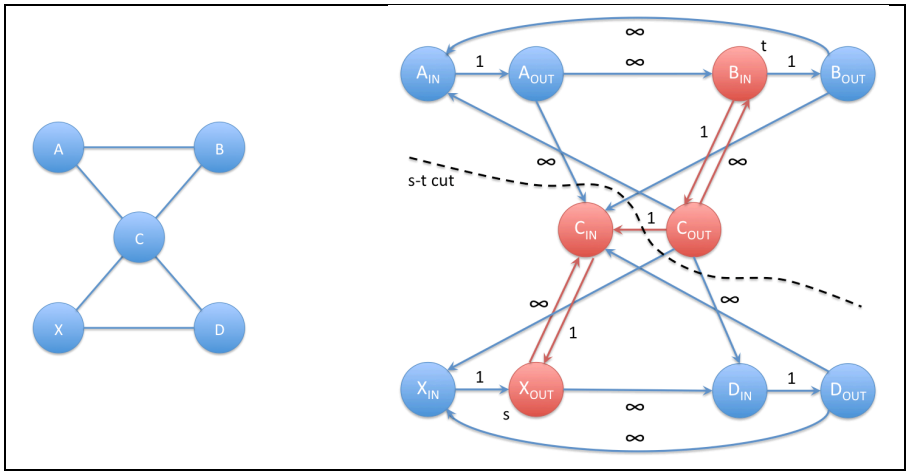

Figure 2: Small sample social network represented as undirected graph with leader X on the left side and as transformed version with split nodes on the right side. The dashed line represents the minimum s-t cut which identifies node C as potential detainee of the iteration with B_{IN} as end node.

On the right side of figure 2 you can see the final residual graph of the iteration with B_{IN} as end node. Expectedly the minimum s-t cut passes node *C* and identifies it as potential detainee.

2. Scenarios

Now that our model is defined, we go through different scenarios and show how this model can be modified to fulfill various requirements. We start with the initial problem and build up further on.

3.1. Biggest Possible Group

In our initial problem we are looking for a way to cut off as many terrorists as possible from the communication network to the terrorist leader. Running Ford-Fulkerson for each possible end node on the modified model from section 2 is sufficient to find the optimal solution. As seen in figure 3 detaining Wadih El Hage and Mohamed Owhali results in separating a group of twelve terrorists from bin Laden. This solution is found by the iteration where Khalfan Mohamed is the end node.

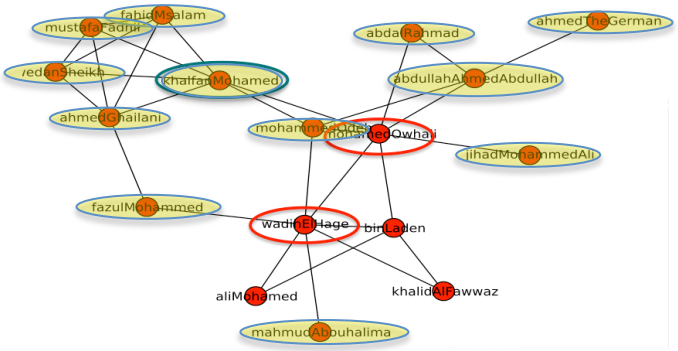

Figure 3: Twelve terrorists can be separated from bin Laden by detaining Wadih El Hage and Mohamed Owhali. Khalfan Mohamed is the designated end node for this iteration.

3.2. Limit the Size of the Separated Group

Separating such a big group may not always be the solution we are looking for. In fact it can lead to a new autonomous terrorist group. So for the second scenario, we limit the size of the separated group. In figure 4 you can see the optimal solution for a group size of maximal four terrorists. This can be achieved by detaining Khalfan Mohamed and Fazul Mohammed. This solution is found by the iteration where Ahmed Ghailani is the end node.

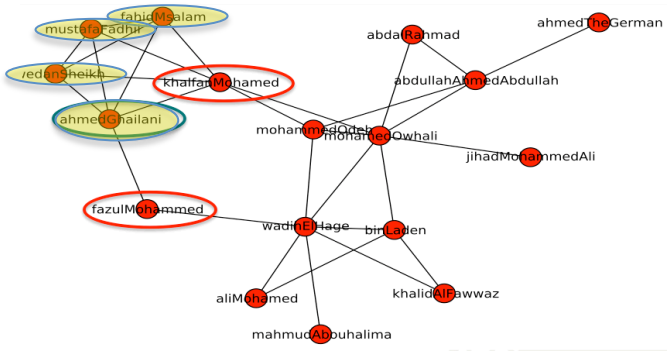

Figure 4: With a size of maximal four for the separated group, we detain Fazul Mohammed and Khalfan Mohamed. Ahmed Ghailani is the designated end node for this iteration.

3.3. Some Terrorists Cannot Be Detained

In our next scenario we assume, that there are some terrorists that cannot be detained for various reasons. For example, we do not know the exact location of this terrorist or he is too well protected. Another possible reason: that this person is an informant and we do not want to lose this source of information. However, in order to protect this node in our network, we increase the capacity on the split-edge of the protected terrorist to infinity.

Assume we protect Wadih El Hage and Mohamed Owhali. We are looking for the biggest possible group to separate. This results in the same solution as seen in figure 4. The biggest separated group is of size four and achieved by detaining Fazul Mohammed and Khalfan Mohamed.

3.4. Show all Possible Combinations

The last iteration of our GAMS code produces an output that shows the members of the separated group and the potential detainees for each possible end node. This output helps a commanding officer decide which terrorist to detain and how to separate a group of desired size from the leader of the terrorist organization.

4. Conclusion

Disturbing a terrorist social network such that we can split off a group from communication with the head of the terrorist organization has a crucial effect on the terrorist leader's influence and opportunities of action. However, this project only exhibits a few scenarios. Future research may focus on the following aspects:

- Limit number of potential detainees
- Add costs/probabilities of detaining a terrorist
- Weighted connections