Dynamic, Covert Network Simulation

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GeoEye Analytics

April 5, 2012

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Motivation

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- There is a lack of open source covert network data.
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- Generating data with DCNS allows us to test network analysis algorithms on a wide variety of networks, for which we know the ground truth.

Objective: Generate a dynamic network which grows and evolves in response to internal characteristics as well as external intervention.

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- The network nodes, V, are *leaders* and *subordinates*
- The network edges, E, are weighted edges which reflect when two nodes have the ability to communicate and work together. Large edge weights indicate the connected members work well together.

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Model Overview: Operations

Tasks

Tasks involve one leader and a subset of that leader's subordinates. These nodes work together to recruit new members to the network and collect resources. At the end of the task, the members travel to a "target location".

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Cooperative Tasks (co-Ops)

Cooperative tasks involve up to three leaders and a subset of those leaders' subordinates. co-Ops are designed to mimic the activities of real terror cells leading up to attacks that have occured in the past. In this presentation, the co-Op discussed is based upon the 2002 terror attacks in Mombasa, Kenya.

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Member Attributes: Overview

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Attributes

- **Leadership**: A node may be a leader or a subordinate. Leaders can organize cells and begin operations while subordinates are members of cells and participate in the operations.
- **Roles**: Determines the node's available actions.
- **Chance of Discovery**: How exposed the member is to external intervention (capture, kill).
- **Radical**: Indicates the devotion of the member to the network. Used for promotion/demotion.

Member Attributes: Roles

Member roles were selected from the JJATT dataset. There are two ways for a node to obtain a role, it can enter the network with the role or it can be given the role during the simulation.

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Available Upon Recruitment	
Sympathizer	Does not do much to help the network
Logistician	Needed for successful task completion
Bomb Maker	Needed for successful task completion
Bomber	Needed for successful task completion
Foot Soldier	Needed for successful task completion
Financier	Collects resources needed for tasks
Weapons	Collects resources needed for tasks
Acquired	
Trainer	Gives nodes new roles
Recruiter	Recruits new members for tasks

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Member Attributes: Chance of Discovery

A member's chance of discovery $x_d \in [0, 1]$ (CoD) indicates how exposed it is to external intervention. A threshold value λ may be set so that any node x with $x_d > \lambda$ is captured or killed.

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CoD Influences

- **Neighbors:** As captured nodes may yield information about other nodes, when a node x is captured or killed, the *CoD* of all x's neighbors increases by the parameter ρ (i.e. $\forall y \in N_x, y_d(t+1) = y_d(t) + \rho$).
- **Location:** At any time, a member may be located in one of three types of locations: hostile (increases x_d), neutral, and friendly (decreases x_d).
- **Secrecy:** Each member is assigned a secrecy score, x_s. Every round, x_s is subtracted from x_d (i.e. $x_d(t+1) = x_d(t) - x_s$). This reflects the fact that some nodes are harder to track than others.

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Radical Influences

- Increases when engaged in an operation
- Receives a bonus for successful completion
- Decreases when not involved in an operation

Network Attributes

Network Security

Network Security, $NS(c_m, k_m)$, is dependent upon the number of members captured/killed, $c_m, k_m \in \mathbb{N}$ in the past $m \in \mathbb{N}$ rounds. Higher NS values result in lower connectivity rates.

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Operation Generation Rate

The probability of a new operation being generated, $P_O(c_m, k_m, r_c, r_k)$, depends on the number of members captured/killed in the past m rounds and the reaction to members being captured or killed, $r_c, r_k \in [-1, 1]$. For example, if $r_c < 0$, then the network will generate fewer operations in response to members being captured.

Node Update Process: Updating Attributes

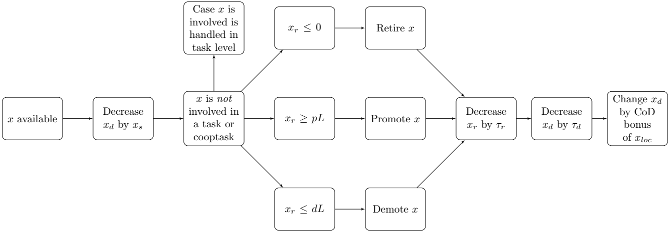

Figure: Node Update Process

Nodes are updated each round in the above process. When a node is involved in an operation, their attributes are updated in the operation update process. Thus, nodes can only be promoted/demoted when they are *not* involved in operations.

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- For all remaining time,

$$w_{t+1}(e_{ij}) = w_t(e_{ij}) + qO_c + sL_c,$$

where $q = 1$ when i, j are involved in the same operation (0 otherwise), $s = 1$ when i, j are in the same location (0 otherwise), and $O_c, L_c \in [0, 0.1]$.

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- When a node x is captured/killed, the neighbors of this node may disconnect from x.

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  - T_r: the amount each member's radical increases each round.

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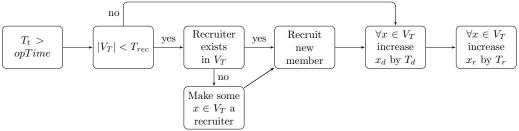
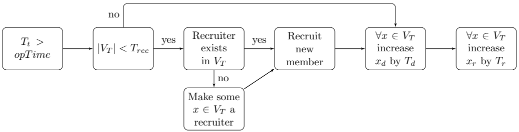


Figure: Preparation Stage

Operations: Tasks



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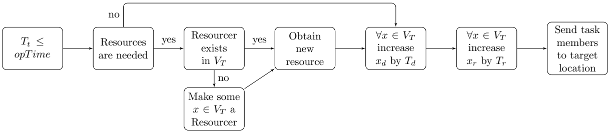


Figure: Operational Stage

Operations: Tasks

End of Task

- For a task to qualify for success, it must have met the recruitment and resource requirements.
- The probability of success is determined by a utility function $U(T)$.
- The utility function used in this simulation averages the edge weights of all involved members using weights of 0 when an edge does not exist.
- Since edge weights grow over time and inexperienced members would have low edge weights, $U(T)$ indirectly captures the experience of the members involved.
- If the task is successful, all of the task members receive bonuses to their edge weights.

Operations: Cooperative Tasks (co-Ops)

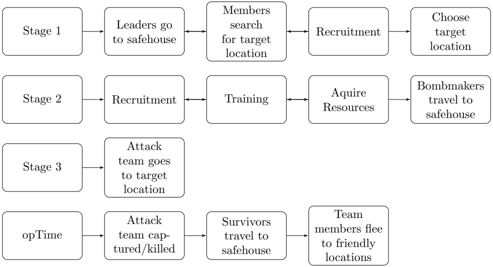


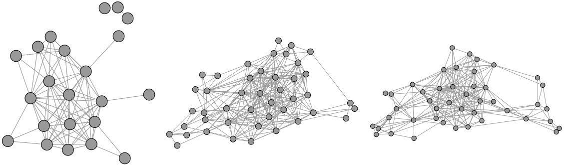
Figure: Mombasa co-Op Attack Sequence

- co-Ops are similar to tasks except they have up to three leaders and the behavior of those involved is more specific.

Results

Although the primary advantage to using DCNS is the ability to generate a wide range of networks, accurately recreating a real, historical network more readily demonstrates the tunability of DCNS. We begin with Jemaah Islamiyah's (JI) network structure in 1995 and simulate the network up to 2005.

Network	Nodes	Edges	Leaders	Avg Degree	Density	Avg Path Length
Real Start	22	83	14	7.55	0.36	1.60
DCNS Sim	44	236	15	10.72	0.25	2.02
Real Finish	45	233	14	10.36	0.24	2.07



(a) JI Start (b) DCNS Sim (c) JI Finish

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- The simulator reacts to external intervention and acts in a cover manner.
- Realistic networks can be generated using the correct parameters.
- Networks with dynamics we have not yet encountered can be investigated and network analysis algorithms can be tested on these networks.
- DCNS allows a researcher to determine the sensitivity of their algorithms to the input networks they test upon.

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Questions?