A Framework for Understanding Botnets

Justin Leonard, Shouhuai Xu, Ravi Sandhu

University of Texas at San Antonio
Overview

Botnet Lifecycle
Botnet Architecture
Command and Control Mechanisms (C&C)
Dynamic Graph Model
Botnet Attributes
Botnet lifecycle

Formation – master compromises, recruits vulnerable machines, and assigns roles.

Command and Control (C&C) – master sends messages to bots

Attack – Bots launch attacks

Post-attack – bots are detected, cured, and new bots recruited.
Botnet Architecture

What roles are present in a botnet?
Master – human attacker(s)
Controllers – coordinates subset of bots, long term asset
Intruders – disposable, high-risk of detection, may downgrade into a bot
Bots – responsible for attacks
Botnet C&C Mechanisms

Anonymous Channels
Sender anonymous channels

Secret Handshakes
Privacy-preserving authentication
PKI-like infrastructure or group signatures

Gossiping
Small fan-out of neighbors
Dynamic Graph Model

Directed graph representation
Vertex set represents bots
Edge set represents “knows” relation – e.g., \((u,v)\) implies \(u\) can spontaneous communication with \(v\).
Does capturing \(u\) imply exposure of \(v\)?
Undirected graph is special case
Dynamic Graph Model

Directed graph represents snapshot of graph over time.
Captures real network behavior – e.g., offline machines, detected and cured bots.
Implies attributes should be modeled as Random Variables instead of deterministic numbers.
Botnet Attributes

Robustness
Resilience
Sustainability
Exposedness
Bandwidth Consumption
Botnet Firepower
Robustness

Minimum number of detections to trace every bot.
Random variable over time
Represents weakest or “best case” detection by defender
Resilience

Captures consequence of exposure of a set of bots

Tracing uses “knows” relationship

Normalized by size of botnet

Intuitively captures how much a defender can achieve with fixed resources (e.g., subpoenas).
Resilience vs Robustness

Robustness establishes minimum number of captures, resilience the effects of a capture – the resilience for the corresponding robustness set is 0.

A set smaller than the robustness cannot capture all bots.

Known to attack *a priori*, defender has limited knowledge.
Dynamic Graph Model

Directed graph representation
Vertex set represents bots
Edge set represents “knows” relation – e.g., \((u, v)\) implies \(u\) can spontaneous communication with \(v\).
Does capturing \(u\) imply exposure of \(v\)?
Undirected graph is special case
Sustainability

Captures effects of interactions between attacker and defender. Uses a definition based on number of connected bots. Reliability from the attacker's perspective against a “malicious” defender.
Exposedness

Worst-case probability a bot is detected by defender due to C&C. Captures the effectiveness of the defenders IDS.

May be used to determine resilience set by using a “detection threshold”, above which we assume a bot is detected.
Bandwidth Consumption

Captures the efficiency of the C&C mechanisms.

Gives an intuitive measure of the “noisiness” of the botnet.

Whole system point of view, as opposed to exposedness, which captures probability of detecting a particular bot based on C&C messages.
Captures the overall effectiveness of the botnet at launching an attack. Simple measure is the size of the botnet. Perhaps also weighted by available resources.
Future Research

Tying definitions to existing botnet case studies.

What strategies are effective at maximizing particular metrics?

Can we quantitatively compare attributes relative to a given defender capability?
Questions?