A Framework for Attack Patterns Discovery in Honeynet Data

By

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A Framework for Attack Patterns' Discovery in Honeynet Data

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Outline

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   - Results of the clique-based clustering
5. Conclusions and Future Work

1. Introduction

The problem

Research context

The problem

- Improve our understandings of certain network threats observed on the Internet
  - Get insights into global attack phenomena
  - Learn more about the *modus operandi*

- To achieve this, we seek to analyze Internet threats at a global strategic level
  - Enable a « Network Situational Awareness » (Yegneswaran, Barford, Paxson in HOTNETS ’05)

Our approach

1. We want to *discover attack patterns* from large real-world attack datasets:
   - Groups of attack traces sharing important similarities
   - No rigid, pre-defined attack signatures
     → Not so helpful with polymorphic and 0-day attacks
2. We seek to systematically *draw knowledge* from those attack patterns

Research Context

- The WOMBAT Project
  - Worldwide Observatory of Malicious Behaviors and Attack Threats
  - EU-FP7 - http://www.wombat-project.eu

Project coordinator:
France Telecom R&D (FR)

Partners from:
Institut Eurecom (FR)
Technical University Vienna (AT)
Politecnico di Milano - Dip. Elettronica e Informazione (IT)
Vrije Universiteit Amsterdam (NL)
Foundation for Research and Technology (GR)
Hispasec (ES)
Research and Academic Computer Network (PO)
Symantec Ltd. (IE)
Institute for Infocomm Research (SG)

Research Context

- Objectives of WOMBAT
  - Aims at providing new means to understand the existing and emerging threats that are targeting the Internet economy and the net citizens

- To reach this goal: three main workpackages
  1. Data acquisition and sharing of security related datasets
  2. Data enrichment with threat context information
  3. Threats analysis: *root cause* identification and understanding of attack phenomena under scrutiny

The focus of this work

2. Honeynet-based forensics

Leurre.com honeynet

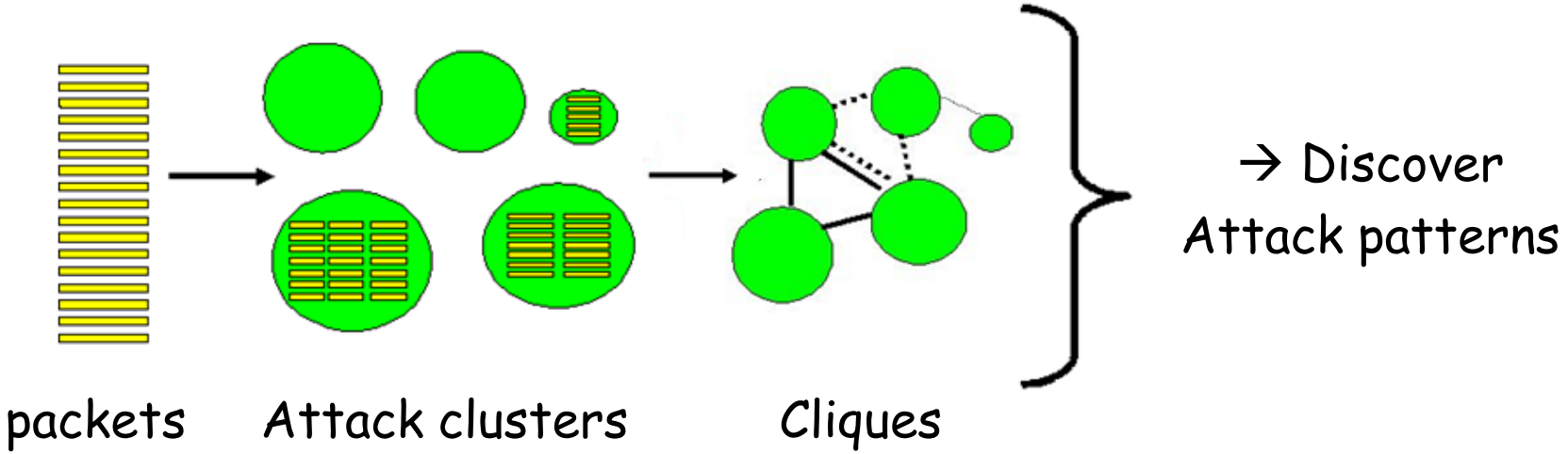
Attack patterns

Leurre.com Honeynet

- Global distributed honeynet (http://www.leurrecom.org)
  - +50 sensors distributed in more than 30 countries worldwide
- Same configuration for all sensors
  - 3 low-interaction honeypots based on *honeyd*
  - 2 x Win2K and 1 x RedHat7.3
- The collected traffic is:
  - Enriched with contextual information (Geo, reverse-DNS, etc)
  - Parsed and uploaded into an Oracle DB
- All partners have full access (for free) to the whole DB

Honeynet-based forensics

- Analyze honeynet traces by means of data mining techniques, in two different steps:
  1. Raw packets → Attack clusters (« fingerprints »)
  2. Attack clusters → discovery of *attack patterns*



Step 1: Attack clusters

- Some *Leurre.com* definitions:
  - A *source* = an IP address that targets a honeypot platform on a given day, with a certain port sequence.
  - Every source is attributed to an "*attack (cluster)*" based on its network characteristics(*):
    - targeted port sequence,
    - #packets,
    - #bytes ,
    - attack duration,
    - average packet IAT, and
    - attack payload (Levenshtein)

Attack tool

↓

Fingerprint(s)

(*) F. Pouget, M. Dacier, **Honeypot-Based Forensics**. AusCERT Asia Pacific Information technology Security Conference 2004.

Step 2: Attack patterns discovery

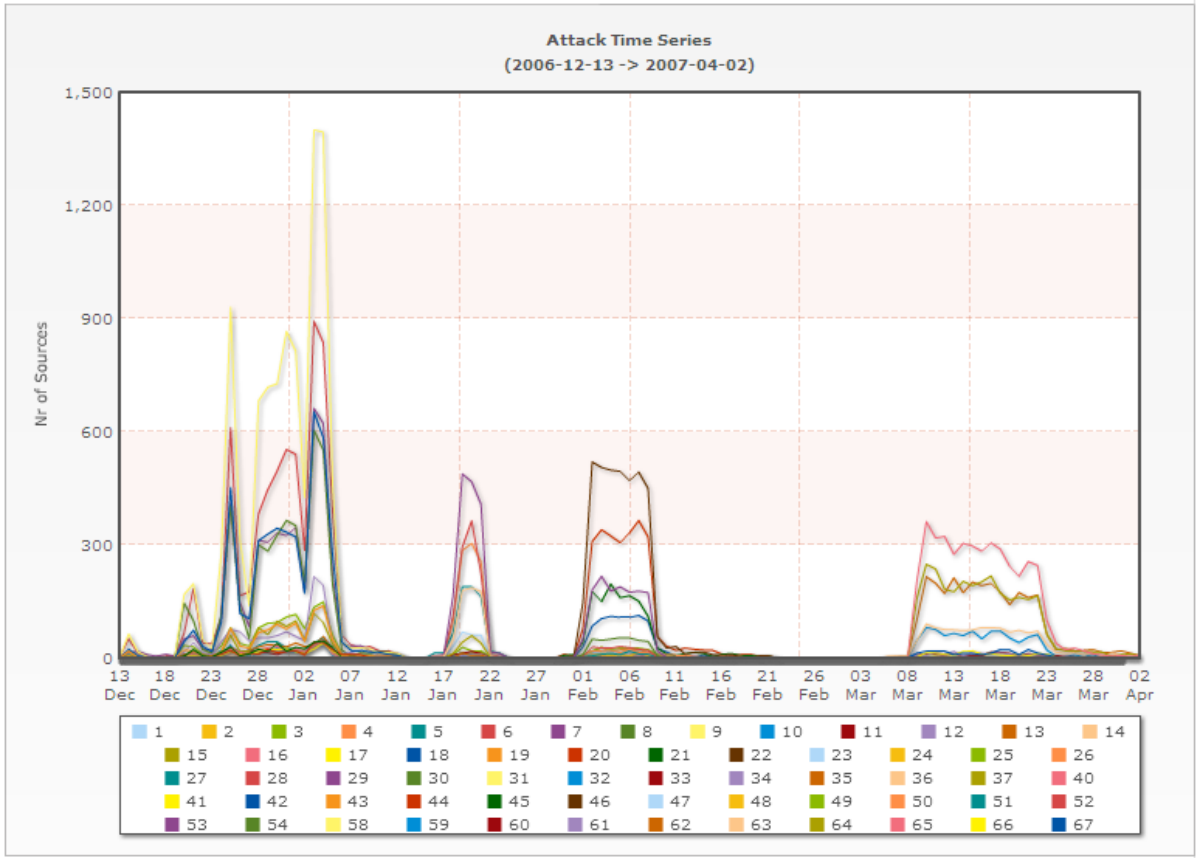
- We use the attack fingerprints to discover *patterns* shared by a group of attacks, by using a data mining process:
  - *Objects* = attack (fingerprints)
  - *Clustering parameter* = selected *attack feature*

- In this work:
  - Clustering parameter → *Attack time series*
    - = aggregated source count by day for a given attack on a given platform

Attack time series

Attack port sequences:

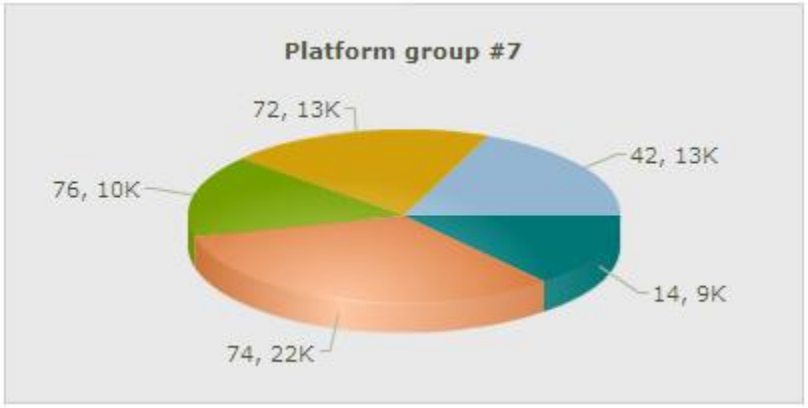
- I
- I-445T
- I-445T-139T
- I-445T-80T



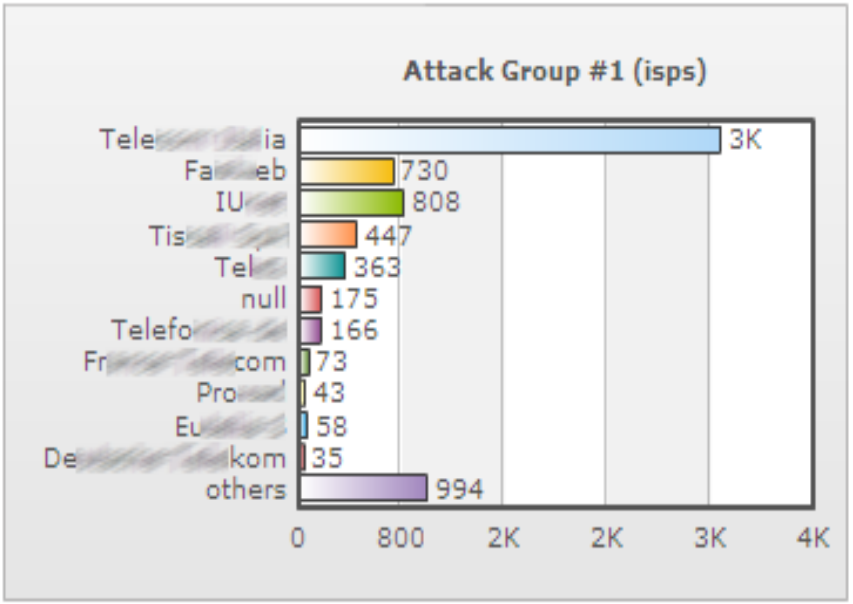
Some other attack features for patterns discovery

- Attackers' characteristics
  - Countries of origin
    - Identify localized botnets
    - Identify "safe harbors" for cybercriminals
  - ISP's and Subnets of origin
    - "uncleanliness" of certain networks
- Targeted sensors

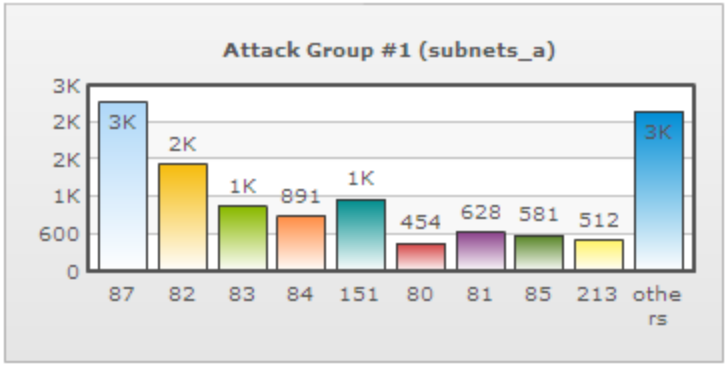
Some other patterns…



Targeted platforms



ISP's of origin



Subnets of origin

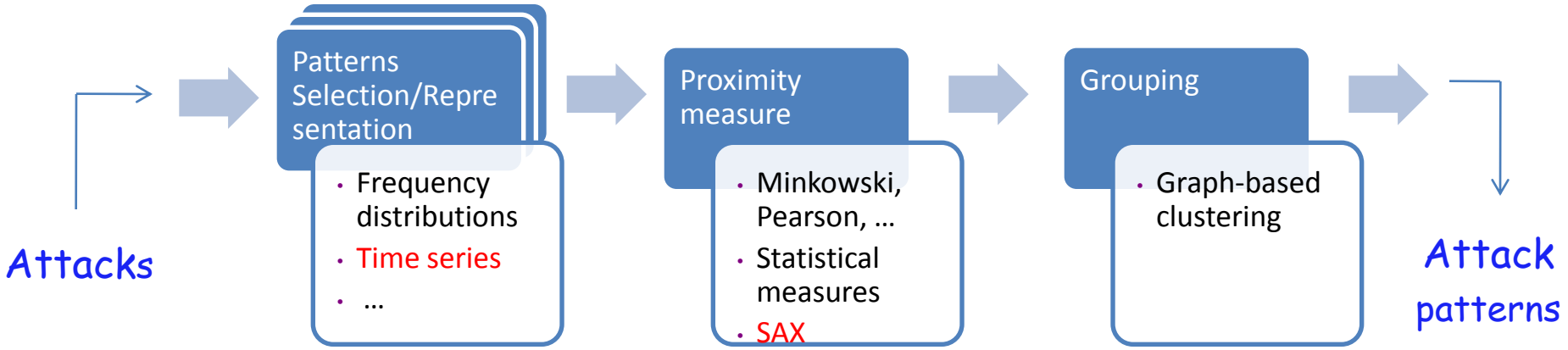
3. Proposed solution

Method overview

Clique-based clustering

Method overview

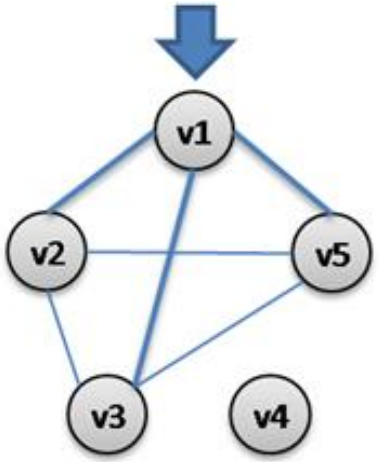
- Basically a KDD application.



Grouping step

- Graph-theoretical formulation
  - The vertices = data objects (e.g. the attack time series)
  - The edges = similarity relationships

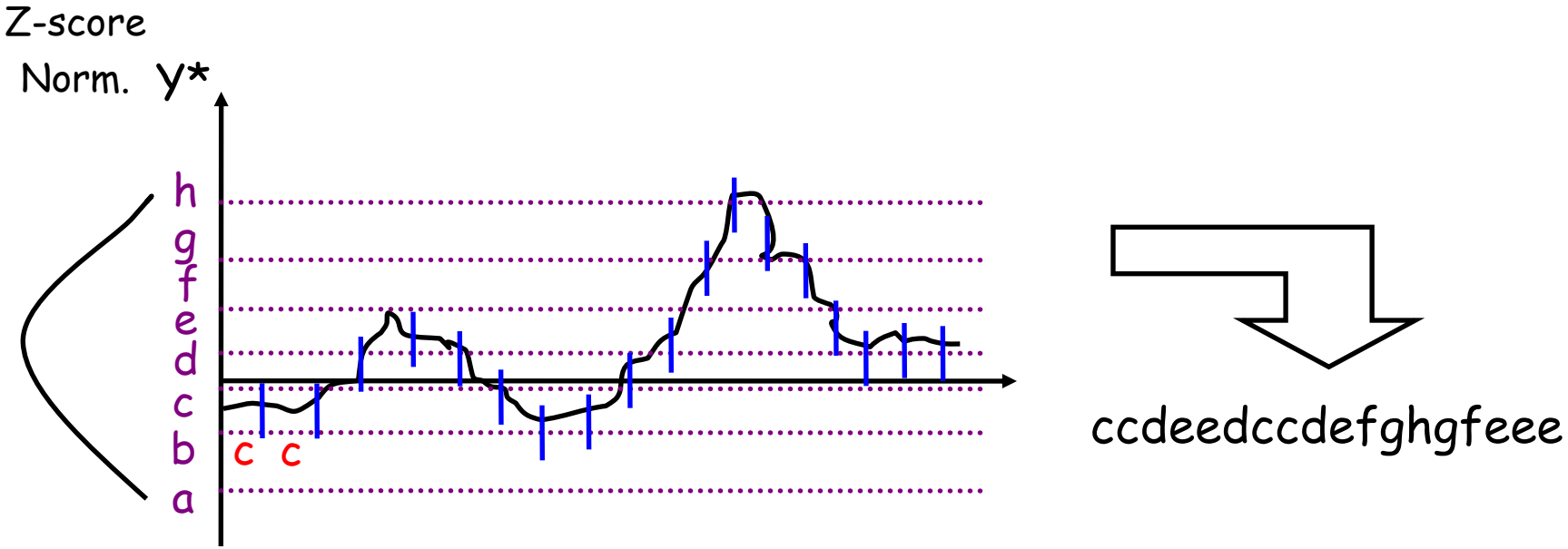
- Clique-based clustering
  - Extraction of *(maximal) cliques*, or complete sub-graphs
  - Greedy algorithm based on the quality of the cliques.



Transitive distance

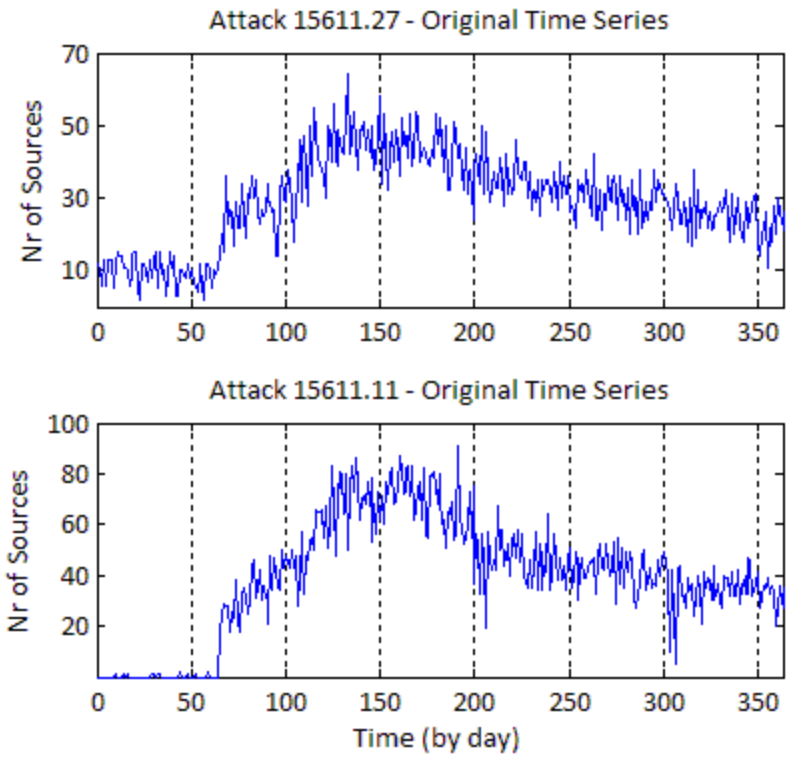
S.A.X.

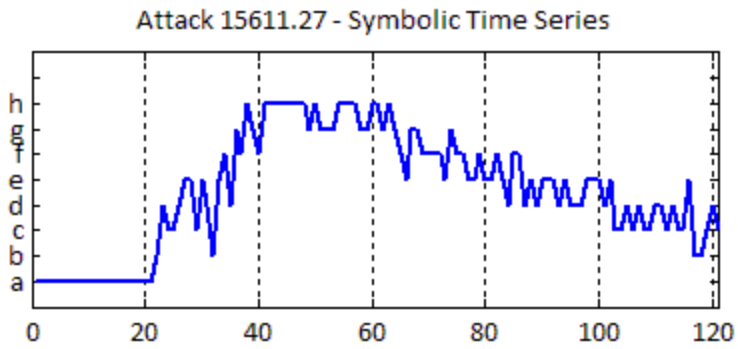
- Symbolic aggregate approximation
  - Per segment, it attributes the mean value to a *symbol*
  - Provides a lower-bounding distance between 2 strings
  - Needs some adaptation to fit to non-Gaussian signals (especially for skewed distributions)

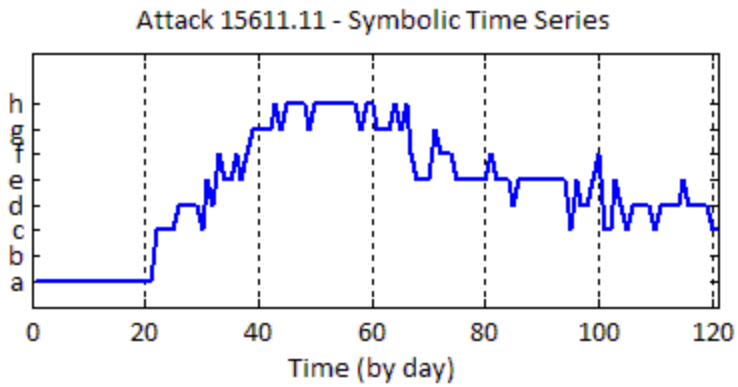


S.A.X.

- An example







4. Experiments

Honeynet Environment

Experimental results

Honeynet environment

- *Leurre.com* dataset used for the experiments
  - Data collected with 44 platforms, located in 22 different countries and IP subnets
  - Period: Sep 1st, 2006 → Jan 1st, 2008 (486 days)
  - Raw data volume: ~27 GB (1,738,565 distinct sources)
- 1268 attack time series, each composed of 486 days
  - Selected on basis of a source volume criterion (at least one peak of activity with min. 10 sources)
  - Corresponds to ~85% of the total traffic data

Cliques results overview

- We observe only three broad classes of activities:
  - **Continous activities** (33%)
  - **Sustained bursts** (12%)
  - **Ephemeral spikes** (6%)

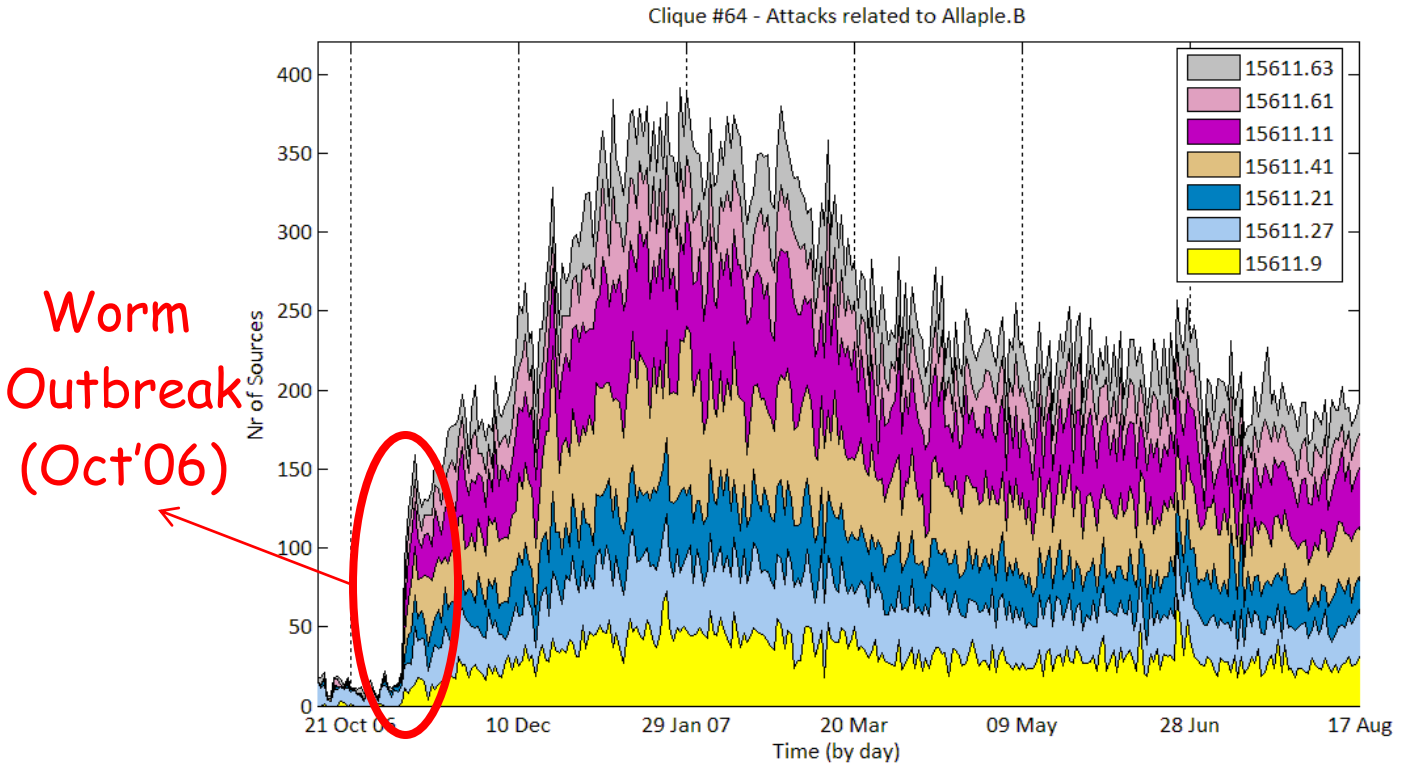
Classes of Activities	Nr of Cliques	Nr of Time Series	Nr of Sources	Main Port Sequences	Plausible Root Causes
Continuous	19	58 (4.6%)	581,136 (33.4%)	|1026U|1027U|1028U |I|139T|445T |1434U |135T |I	Scam on Messenger Svc Classical worms (Allaple.B, Slammer) Continous scan
Sustained Bursts	24	107 (8.4%)	204,336 (11.8%)	|I|445T|139T |5900T and |1433T |2967T, |2968T |445T	Large botnet activity Multi-headed worm Sustained scan activities
Ephemeral Spikes (Epiphenomena)	109	554 (43.7%)	98,610 (5.7%)	|6644T, |17838T, |6769T |5168T, |53842T, |12293T |6211T, |50286T, |9661T |135T, |139T, |445T |2967T, |2968T |1025T, |80T, |1433T |5900T, |5901T |4662T, |4672T	Ephemeral probes on unusual high TCP ports Targeted scans on common Windows ports (NetBios, Symantec, RPC, VNC, etc) Misconfigurations (P2P)
Inconsistencies or misclassifications	12	36 (2.8%)	25,716 (1.5%)	|135T, |139T, |445T |1433T	Background noise on common services

Continuous activity

A clique of attacks observed on 7 different sensors, targeting:

|I, |I|139T, and |I|139T|445T

(root cause: **W32/Allaple.B**)

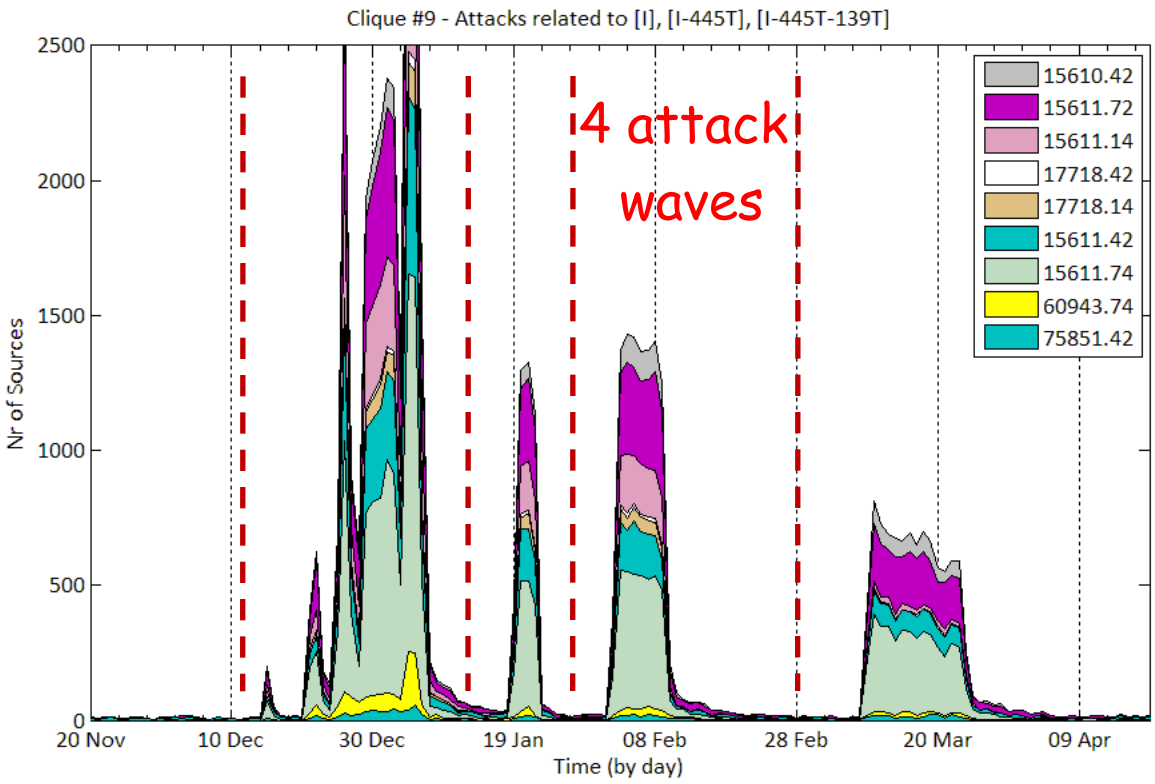


Sustained Bursts

A clique of attacks observed on 3 different sensors, targeting:

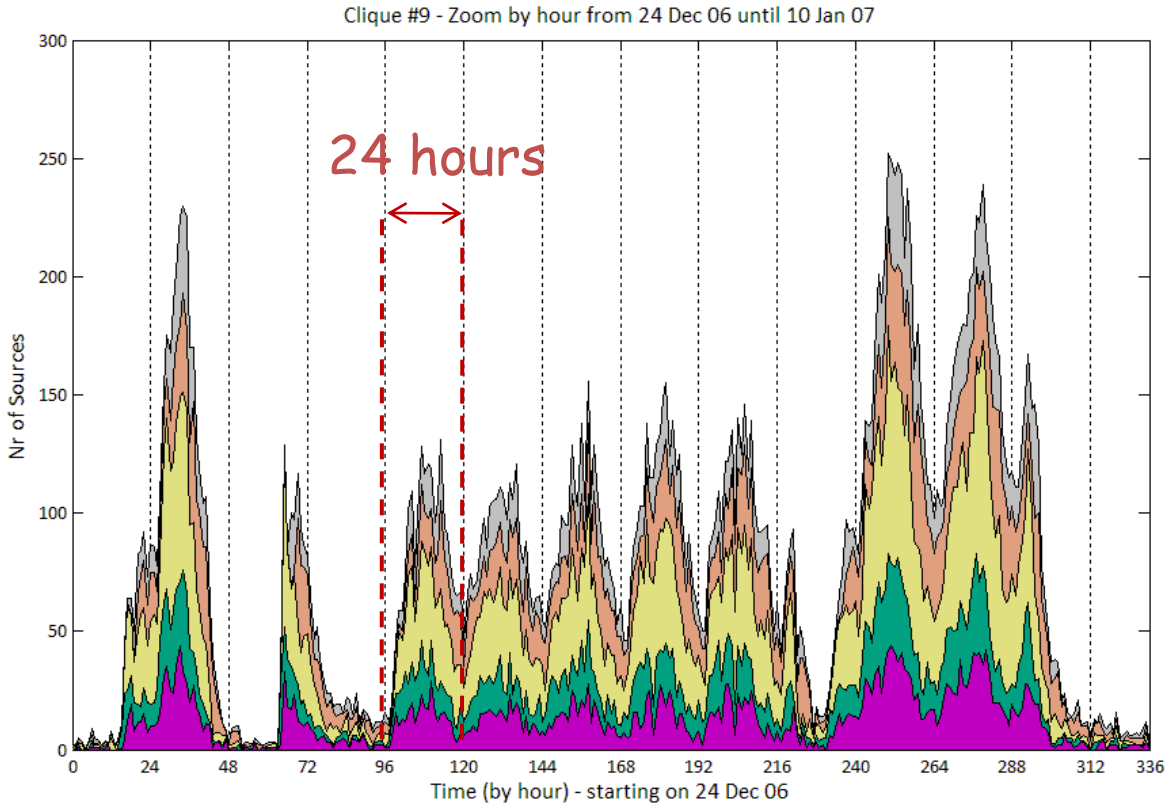
|I, |I|445T, |I|445T|139T and |I|445T|80T

(presumed root cause*:* ***botnet propagation***)



Sustained burst: A zoom on the 1st wave

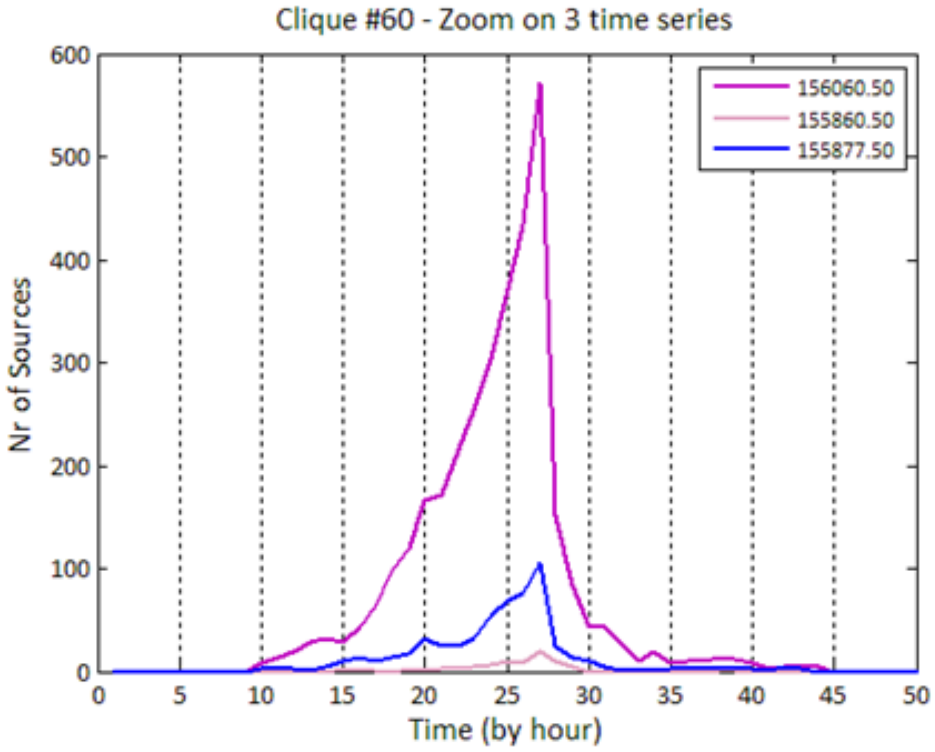
- Time frame: 24 Dec until 10 Jan
- Time granularity: *1 hour*



Ephemeral Spikes

A clique of attacks observed on a single sensor, targeting:

|6769T (root cause: ??)



5. Conclusions

Strengths / limitations

Future directions

Strengths of the framework

- Can discover any sort of attack pattern via attack trace similarity
  - Rather than via rigid signatures
- Resistant to *polymorphic* attack tools
- Can produce concise, high-level summaries of attack traffic, which deliver much more insights into global attack phenomena and their *modus operandi*

Some limitations

- Currently, no information is *automatically* provided regarding the type of attack, i.e.:
  - Botnet or worm propagation?
    - → We look to implement some techniques to separate botnet, worm and misconfigurations within attack events.
  - Name or family of the botnet / worm / malware ?
    - → Recently we've upgraded our threats collection infrastructure with controlled high-interaction honeypots based on SGNET (*)
    - → SGNET = ScriptGen + Nepenthes + Argos + Anubis + VirusTotal

(*) Corrado Leita and Marc Dacier. **SGNET: a worldwide deployable framework to support the analysis of malware threat models.** (EDCC 2008, Lithuania)

Future work

- Botnet / worm patterns separation
- Integration of other *relevant* attack features:
  - Malware characteristics (e.g. from SGNET traffic)
  - External contextual information
    - IP Data from other projects (Shadowserver, EmergingThreats, SpamHaus, …)
- Combination of many different attack features
  - Generation of higher-level "concepts" describing real-world phenomena
    - A concept is similar to a hyperclique
  - Knowledge engineering based on extracted concepts

Thank you.

Any question?

If you'd like to join *WOMBAT* or *Leurre.com* projects, please do not hesitate to contact us:

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