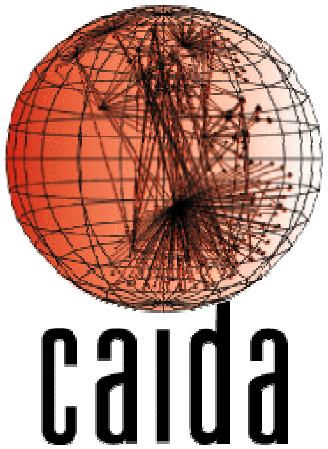
Anomaly Sampling
(bringing diversity to network security)

David Moore



CAIDA
University of California, San Diego

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Ok, let's get it out of our system

- "Sampling" by itself is a general term, like "aggregation".
  - Sampling: ≈ {things of type X} → smaller {things of type X}.
  - Aggregation: ≈ {things of type X} → smaller {things of type Y}.
  - Both:
    - Turn "too much stuff" into "hopefully enough stuff" to solve problems that *you* care about.
    - Useful at multiple stages of data collection, data management and analysis. Hierarchical approaches are very nice.
- Note: "rotating pcap files, keeping the last 3 days" is **sampling**, with algorithm: sample all packets less than 3 days old.

Ok, let's get it out of our system

- Sampling is not always keep/discard.
  - Sampled items could be given higher priority.
  - Sampled items might be separately kept to allow more efficient initial analyst queries against the dataset. (Same with aggregation)
  - Sampled items may be sufficient for a variety of basic reports which would save processing, etc..

- So…, in this presentation, "sampling" has no direct relationship to the ongoing packet / flow sampling argument ^H^H^H^H^H^H^H^H discussion.
  - You could imagine using this on a stream of packets, or a stream of flows, or syslog entries. Please, imagine that.

Anomaly Sampling

(bringing diversity to network security)

Flagging

Prioritization

Potential Initial Query

Optimizer

Detection

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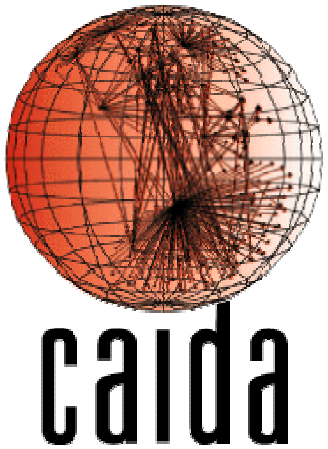

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Basic Idea

- Existing systems focus on accurate counting of packets (or bytes) for large traffic aggregates
  - e.g., Smart Sampling, Traffic Summaries, Adaptive NetFlow, …

- Instead, focus on **interesting, *new*** information

Why? – Operational Network Security

- Forensics – “Bad guy did something”
  - When did they do it?
  - How did they do it?
  - What other machines did they get?
- Detection
  - Host ABC unexpectedly responded to a probe
  - Host XYZ used a service it never did previously

Living on the Network Edge

- The problem is **ours**, not our customer's.
- We care about **all** of the hosts.
- But each as an **individual**.
  - Some hosts are naturally more important.
  - Each host has its own services, risks, users, threats to other resources, ….
- We care about **small** events, not affecting performance.
- The problem remains **after** the "event" is over.
- Monitored network bandwidths are still high.

Basic Idea

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  - e.g., Smart Sampling, Traffic Summaries, Adaptive NetFlow, …
- Instead, focus on **interesting, *new*** information

What is "interesting" and "new"?

- Imagine you are the poor recipient of collected network data. What do you see?
  - Here's a record about our web server. Oh, and here's another record about our web server. And our mail gateway. Oh, here's another packet about our web server, ….
- Please, tell me something ***I don't know***
  - Tell me what is "abnormal", "unusual" or "new".
  - Tell me "just enough" about **everything**.
  - Do not prioritize telling me redundant information.
- These change over time.

System Components

- Diversity Score Assigner
  - Module assigns vague, relative rankings to items (packets, flows, …) based on how similar/different this item is to previously seen items.
  - Many different approaches for this, but there appear to be a decent set of them which cover a wide range of uses when given some parameters.
  - Some approaches are very efficient in memory or CPU requirements.
- Sampling Rate Adjustor
  - The scores produced above are based on the data stream without any knowledge of the desired sampling rate.
  - Variety of algorithms to dynamically keep effective sampling rate near the target sampling rate, while maintaining diversity score information.

Feature Spaces

- Operator chooses sets of fields/etc. over which they want coverage: (e.g.)
  - Source IP address
  - Destination IP address
  - Source & destination IP address pair
  - Protocol, source port, destination port
  - Src. IP addr., protocol, src. port
  - Src. IP addr., protocol, dst. Port
  - …
- Might chose weights to specify relative importance

Controlled Experiment

- Packet trace of live traffic in and out of central computing and network operations building (at university).
- Trace happens to contain some centralized nessus and nmap scanning from network operations. Plus main campus web servers, mail servers, desktops, ….
- Inserted an IRC exchange between 1 server and 3 clients
  - B → X, X → B (message, TCP ACK)
  - X → A, X → B, X → C, X → D (message broadcast)
  - A → X, B → X, C → X, D → X (TCP ACKs)
  - 10 packets for entire exchange, 8 unidirectional flows, 4 bidirectional flows.

Experiment Results

Target Rate	1 / 10
Filter	None
Scheme	Random
Saw at least 1 of IRC test	64%
Avg. # of test packets seen	0.92

Experiment Results

Target Rate	1 / 10	1 / 10
Filter	None	Discard top 85% of traffic
Scheme	Random	Random
Saw at least 1 of IRC test	64%	100%
Avg. # of test packets seen	0.92	7.73

Experiment Results

Target Rate	1 / 10	1 / 10	1 / 1000
Filter	None	Discard top 85% of traffic	None
Scheme	Random	Random	Diversity Counting
Saw at least 1 of IRC test	64%	100%	100%
Avg. # of test packets seen	0.92	7.73	4.66

Experiment Results

Target Rate	1 / 10	1 / 10	1 / 1000	1 / 5000
Filter	None	Discard top 85% of traffic	None	None
Scheme	Random	Random	Diversity Counting	Diversity Counting
Saw at least 1 of IRC test	64%	100%	100%	100%
Avg. # of test packets seen	0.92	7.73	4.66	1.26

Conclusions

- Anomaly detection is radically different for security at the edge compared with performance inside an ISP.

- *Appropriate* sampling techniques can:
  - greatly reduce the amount of data to look at (either by human or software)
  - focus attention on new, interesting events
  - provide good coverage for first-pass forensics analysis

- This approach can be applied to many streams of data: packets, flows, syslog, web logs, …

Internet Measurement Data Catalog http://imdc.datcat.org/

- To facilitate searching for and sharing of data
  - Index as much as possible, including datasets not publicly available
  - DatCat doesn't store any network data itself
- To enhance documentation of datasets via public annotations
  - Easy place for anyone (not just the dataset creator) to provide additional information
- To advance network science by promoting reproducibility
  - Paper X ran their detection algorithm on dataset X and had a false positive rate of 0.2. Using our algorithm on dataset Y, we get a false positive rate of 0.1. Therefore our algorithm is better. …
  - Persistent handles to allow for consistent citing and comparison:

http://imdc.datcat.org/collection/1-003M-5=AOL+500k+User+Session+Collection

DatCat

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