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Indexing Full Packet Capture Data With Flow

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Overview

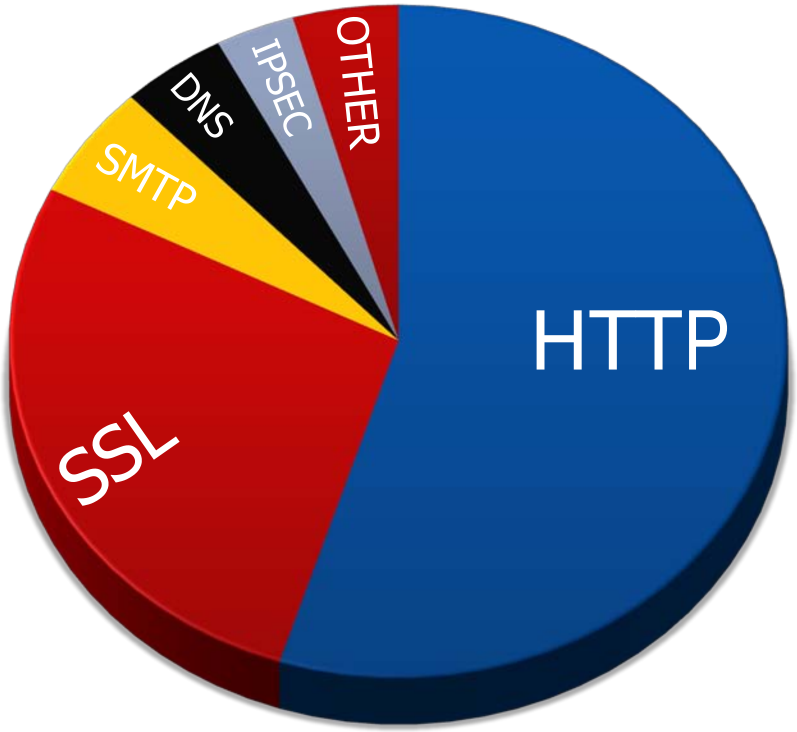
- Full packet capture systems can offer a valuable service provided that they are:
  - Retaining full fidelity data
  - Providing access to that data in a timely manner

- This discussion outlines lessons learned in developing a full packet capture system that meets these needs by using:
  - Abstracted flow representations
  - Application data extraction
  - Data indexing and caching

Goal: A full packet capture system capable of returning all relevant information quickly

Keeping Up With the Threats

- Know your threats
  - DOS
  - Data loss
  - Email phishing
  - Covert channels
- Know your sensors
  - What data is kept
  - How long can it be retained
  - How long it takes to retrieve
- Data is useless if it's not actionable

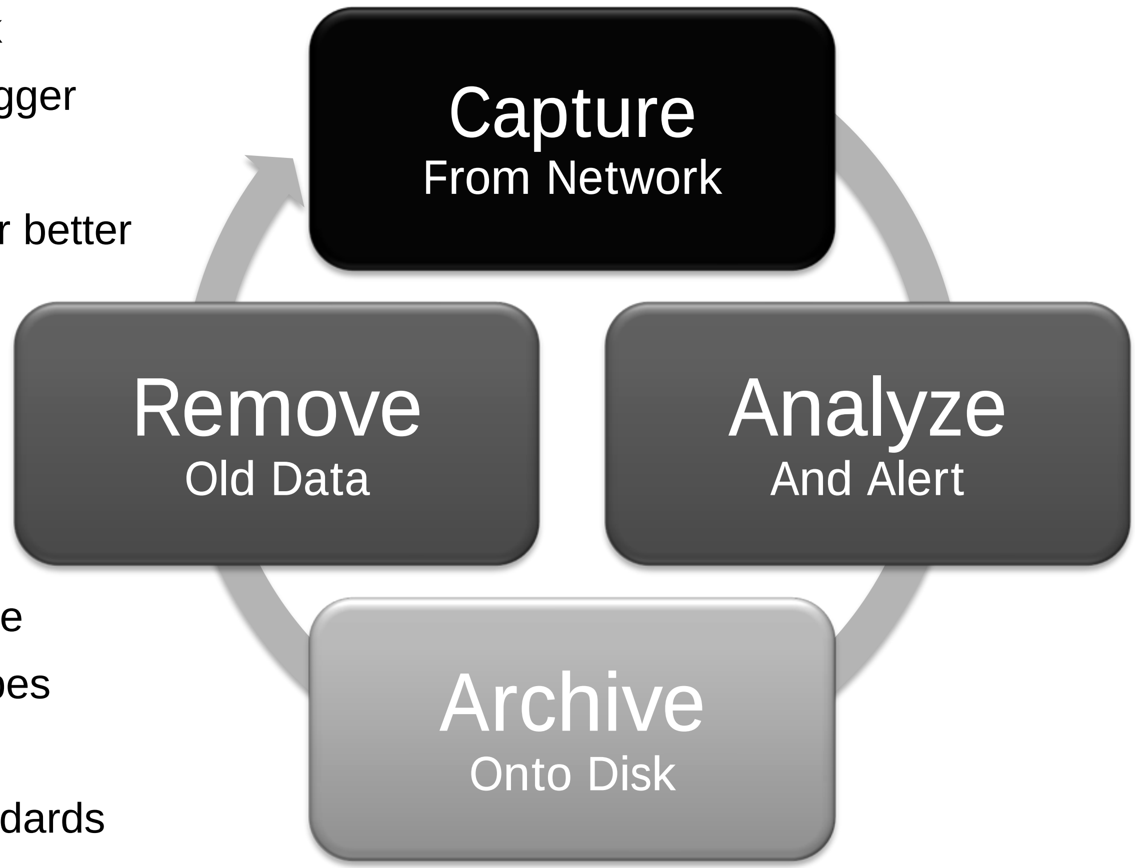


Protocol Distribution

The threats drive system design

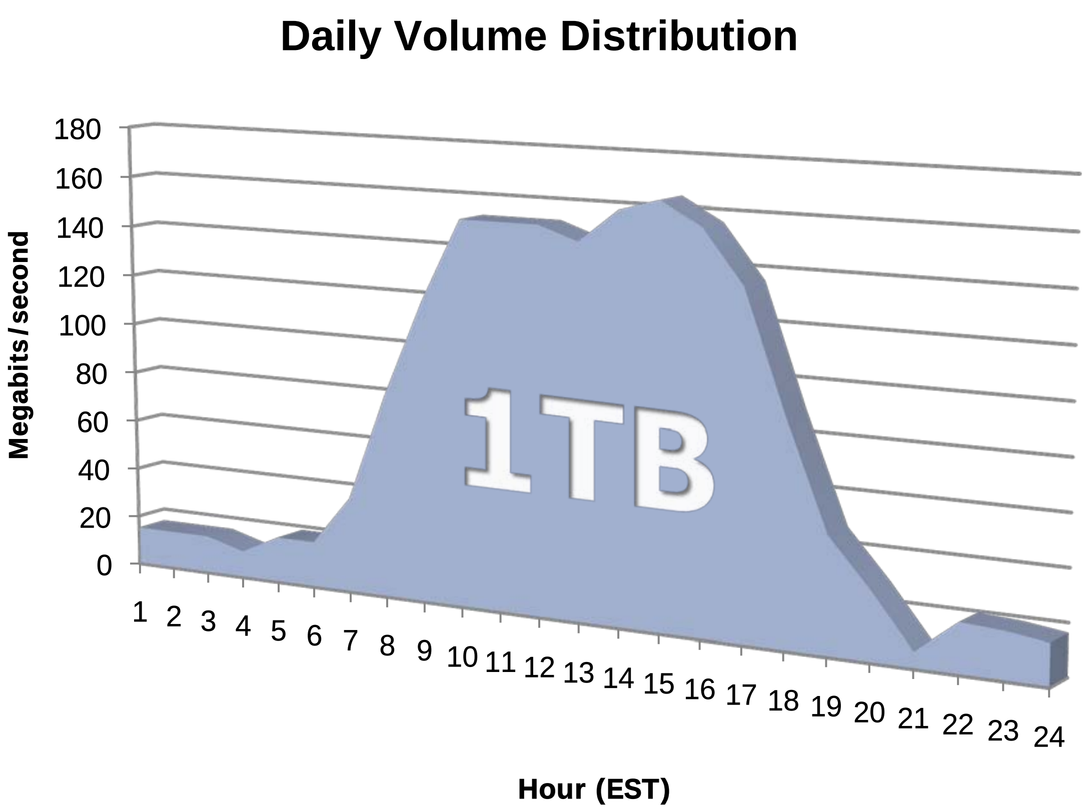
Full Packet Capture Cycle

- Capture Process Cycle
  - Capture Data from Network
    - TCPdump, DaemonLogger
    - Rollover every X MB
    - Capture to RAMdisk for better performance
  - Analyze
    - Network and strings
    - Anomalies
  - Archive
    - Save data for future use
    - Pre-process certain types
  - Remove
    - Maintain retention standards



Volume Estimates

- Full packet capture of a saturated 1 Gbps link will yield:
  - 1 Day = 6TB
  - 1 Week = 42TB
  - 1 Month = 180TB
- Data is stored on sensors
  - Moving data to central storage would duplicate all traffic, not an option.
  - Data will be queried on sensors as well – causes disk I/O contention.



“Sensing” a Problem

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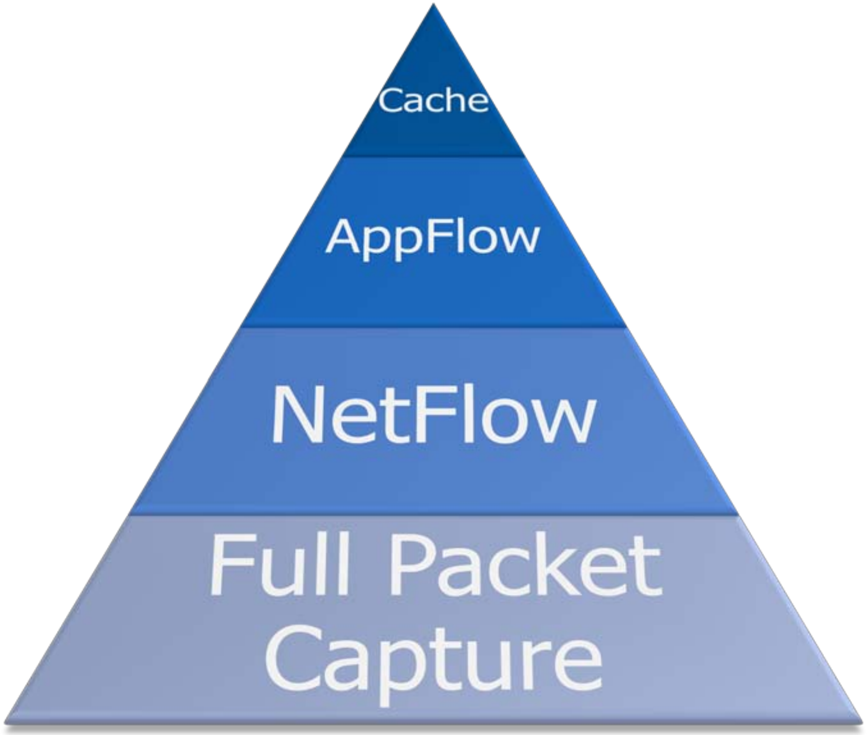
- Indicators can be vague
  - “Anti-virus labs report a new malicious domain, www.badguy.com, has been used since December 15, 2010 to exploit vulnerable versions of web browsers.”

- My initial thoughts:
  1. Do I still have PCAP data from December 15?
     - Saving 1.5 months of full packet capture logs will be close to 45TB.
  2. Do I search for December 15 or the last 1.5 months?
     - Searching through 1 days worth of full packet capture logs using regular expressions on all port 80 data will take 6 hours. A query for 1.5 months will take 11+ days to complete.
  3. Should I filter on subject or URL?
     - Do both, because I don’t have an extra 11 days to wait for any subsequent queries.

Tiered Architecture

- Linear analysis of full packet capture files does not scale
  - Too much time is wasted searching for the needle in the haystack
  - File creation time is the only index provided by the capture, major inefficiency
- Possible Solution: A tiered schema to support analytical needs
  - High-fidelity data
  - Quick results using smart indices
  - Long data retention



Tier 1: Full Packet Capture

- Record all bytes captured off the wire using LibPCAP
  - TCPdump
  - DaemonLogger from Snort
- PCAP files are saved onto disk for analysis
  - TCPdump – rotates every X MB's
  - DaemonLogger – can rotate by size or time interval
  - Filename useful if saved in format:
    - YYYY-MM-DD_HHMMSS.pcap

PCAP Archive

2011-01-23_000000.pcap
512MB

2011-01-23_000121.pcap
512MB

2011-01-23_000342.pcap
512MB

2011-01-23_000820.pcap
512MB

1 Day of Full Packet Capture

- 1TB of disk space used
- 6 hours to query all data

Tier 1: Full Packet Capture – Use Case

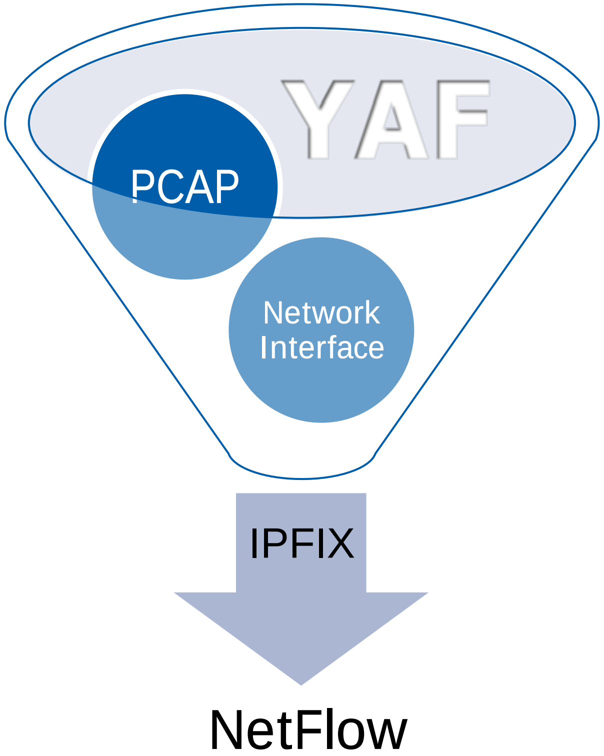
Call For Data:

Identify traffic to www.badguy.com in the last 24 hours.

- Search PCAP files for regular expression:
  - `/^Host: www.badguy.com/`
  - Limit to port 80 for efficiency by use of BPF
- Effectiveness:
  - Accurate, low amount of false positives
- Cost:
  - Disk I/O: Reading 1TB (2,000 512MB files) of data may hinder other disk-bound applications, such as the capture process
  - Speed: Up to 6 hours for query to complete, not acceptable

Tier 2: NetFlow

- Flowmeter used to produce a Netflow representation of full packet capture data
  - SiLK YAF
  - softflowd
- Provides layer 4 summary*
  - *YAF applabel feature identifies some protocols



1 Day of NetFlow Capture

- 1GB of disk used
- 1 minute to query

Tier 2: NetFlow – Use Case

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Call For Data:

Identify traffic to www.badguy.com in the last 24 hours.

- Search NetFlow records:
  - `--dip=[IP address of www.badguy.com]`
- Effectiveness:
  - Low accuracy: traffic may be for another virtual host using the same IP
  - Limited context: protocol information is not given by NetFlow, this could be a non-HTTP process listening on port 80
- Cost:
  - Disk I/O: Reading 1GB of packed NetFlow is relatively low
  - Speed: Within several minutes for query to complete

Tier 3: AppFlow

- Looking for the best of both worlds:
  - The speed of NetFlow
  - The fidelity of full packet capture

- AppFlow- a hybrid approach:
  - Unique list of relevant attributes are extracted from each full packet capture file
  - Extract attributes that are the source of most queries:
    - **SMTP** - header elements, attachment filenames
    - **HTTP** – URI’s, user-agent strings, SSL certificate attributes
    - **DNS** – question/answer attributes
    - **Layer 3** – source IP, destination IP
  - Context is provided by the associated full packet capture file

1 Day of AppFlow

- 200MB of disk space used
- 4 seconds to query data

Tier 3: AppFlow

- Relevant attributes from each Full Packet Capture file are extracted into a corresponding AppFlow file

Full Packet Capture	**2011-01-23_0000.pcap** 512MB	**2011-01-23_0007.pcap** 512MB	**2011-01-23_0010.pcap** 512MB
AppFlow	**2011-01-23_0000.appflow** 124KB joe_smith@example.com Meeting next week www.example.com/ /files/document.pdf host.example.com Meeting_2011_01_24.doc 2015-10-22 05:00:00	**2011-01-23_0007.appflow** 92KB test.example.com Fwd: Upcoming event bob@example.com Re: Wainscoting quote 10.132.53.21 /cgi-bin/temp/index.html	**2011-01-23_0010.appflow** 145KB Fwd: Upcoming event bob@example.com Re: Wainscoting quote 10.132.53.21 /cgi-bin/temp/index.html ftp.example.com jnorthrop@example.com /get_weather.php test.example.com

Tier 3: AppFlow – Use Case

Call For Data:

Identify traffic to www.badguy.com in the last 24 hours.

- Search AppFlow records:

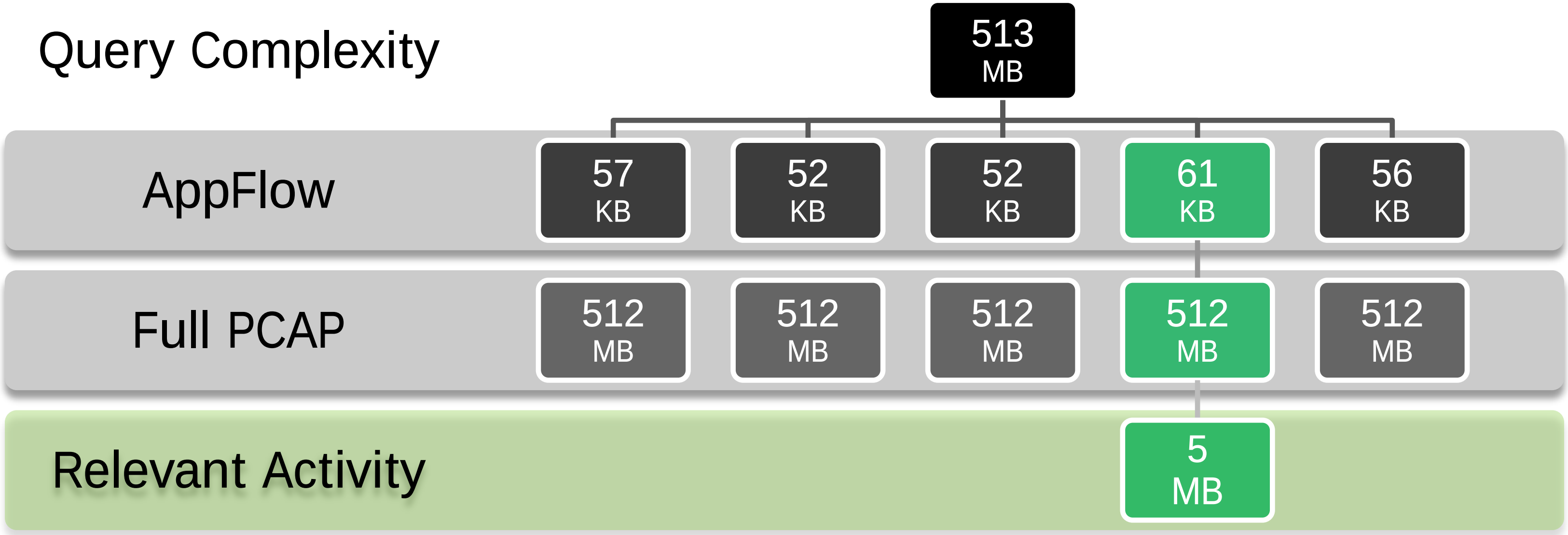
```
$ grep 'www.badguy.com' 2011-01-22*.appflow
    2011-01-22_034521.appflow: www.badguy.com
    2011-01-22_083200.appflow: www.badguy.com
```

- Effectiveness:
  - Decent Accuracy: 'www.badguy.com' may be part of an HTTP, SMTP, or DNS flow
  - No context: there is no association to the traffic

- Cost:
  - Disk I/O: Very low
  - Speed: Very fast

Data As An Index

- AppFlow serves as an efficient index for full packet capture files
  - Determine, “Is value X in the AppFlow index”?
    - Yes: then query the associated full packet capture file for related data
    - No: skip to the next file
  - Reduces disk I/O and query time by identifying the relevant full packet captures files



More Efficient Indices - Bloom Filters

- Most analytical queries start with the question, “does this value exist in a set of data?”
- Bloom filters are specifically designed to answer that question[1]
  - Great use-case presented by Chris Roblee in FloCon 2008 [2]
  - Use a hashing algorithm to store a set of values
  - Returns a Boolean response to the existence of a value in a set
  - Can produce false positive but no false negatives
    - The probability of false negatives is tunable but more reliable Bloom filters increase the data structure size
- Easy to store AppFlow data in a Bloom filter
  - Convert file to Bloom filter in 14 lines of code
  - Store on disk as a serialized data structure

1 – Ripeanu & Lamnitchi - www.cs.uchicago.edu/~matei/PAPERS/bf.doc/

2 – Roblee - Hierarchical Bloom Filters: Accelerating Flow Queries and Analysis - http://www.cert.org/flocon/2008/presentations/roblee_bloomdex-flocon2008.pdf

Bloom Filter Efficiency

- How well Bloom filters perform:
  - Sample: 1 day of full packet capture data
  - Query speed and storage efficiency drastically increase
  - The two operations complete in the same amount of time (6 hours):
    - Querying 1 day of full packet capture data
    - Querying 50+ years of AppFlow Bloom filters

Data Type	Size	Query Time	Time Speedup	Storage Efficiency
Full Packet Capture	1 TB	6 hours	-	-
AppFlow	200 MB	4 seconds	5,400x	5,000x
AppFlow Bloom Filter	20 MB	1 second	21,600x	50,000x

Tier 4: Caching

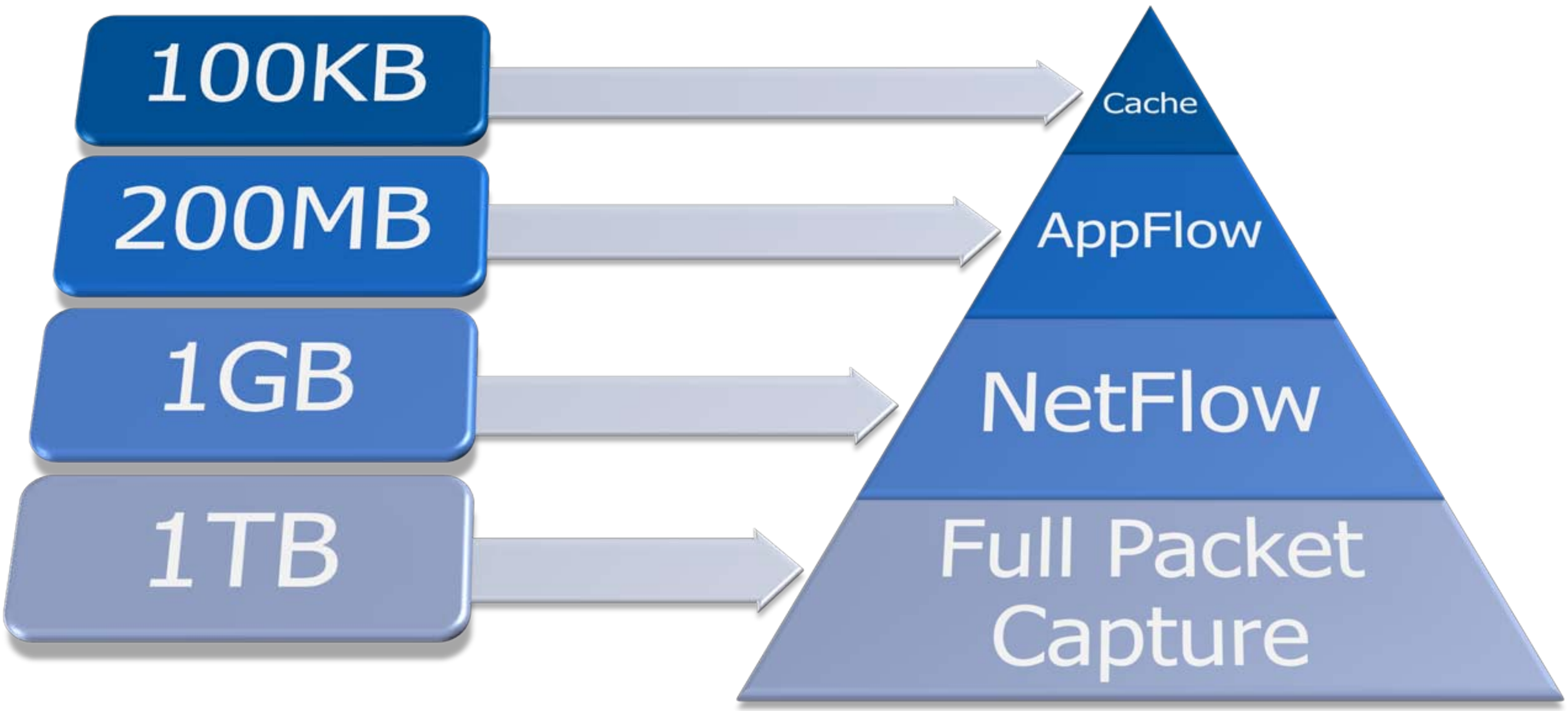
- Bloom filters produce limited false positives
  - Associated full packet capture files must be queried to determine which are incorrect
  - That operation can be costly but is ultimately necessary with any index
  - Analyst clustering - the problem worsens when multiple users are conducting similar queries, each making the same mistakes

- Limit the amount of redundant queries for false positive results by caching the correct results in memory
  - memcached[1] - an open-source distributed memory caching system
  - Distributed: values can be retrieved, set, or updated from remote systems
  - Values to store:
    - Paths to PCAP files with relevant information
    - Time range, BPF, and path to query result PCAP file

1- http://memcached.org

Tiers of Comparison

Data Storage Requirements
For a Single Day



Conclusions

- Full packet is here to stay because the network will remain common to most incidents
- Attack vectors will change so tools need to remain flexible
- Indexing abstracted flow representations is one method for improving the gap between indicators and identification.

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