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Visualization of large scale Netflow data

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Preface

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

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Chapter 1 Background

1.1 NetFlow

Cisco IOS NetFlow creates an enviroment that have the tools to understand who, what, when, where and how network traffic is flowing. This makes it easier for administrators to utilize the network as optimal as possible. One can determine the source and destination of traffic and use this information to reveal for example DDoS-attacks or spam mail.

1.1.1 How dies it work?

Every packet that is forwarded within a router/switch is examined for a set of IP packet attributes. With these attributes one can determine if the packet is unique or similar to other packets.

The attributes used by NetFlow are:

– IP source address

– IP destination address

– Source port

– Destination port

– Layer 3 protocol type

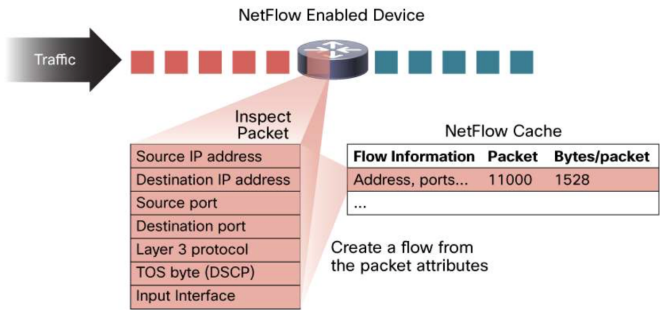
– Class of service

– Router/Switch interface

To group packets into a flow, one compares source/destination IP address, source/destination ports, protocol interface and class of service. Then the packets and bytes are tallied. This method is scalable because a large amount of network information is condensed into a database of NetFlow information called the NetFlow cache.

When the NetFlow cache is created one can use this to understand the network behaviour. The different attributes generate different knowledge about a certain network, and combined they can paint a detailed picture of how the network is working. For example the ports show what application is utlizing the traffic, while the tallied packets and bytes show the amount of traffic.

Lime inn hvordan det ser ut i kommandolinjen



1.1.2 Main components

A typical setup using NetFlow consists of three main components:

- **Flow Exporter:** aggregates packets into flows and exports flow records towards one or more flow collectors.
- **Flow collector:** is responsible for reception, storage and pre-processing of flow data received from a flow exporter.
- **Analysis application:** an application that analyze the received flow data in different contexts, such as intrusion or traffic profiling.

1.2 Data visualization

Data visualization refers to the techniques used to communicate data or information by encoding it as visual objects[sitere?]. Meaning that information is represented trough any visual element such as graphs and plots, but may also take any other visual form. Visualization helps users analyse and interact with data in a whole new way. It makes complex data more accessible, understandable and usable.

In recent years the rate of which data is generated has increased rapidly, and the need for information to be available and comprehensible is growing. All these new sources of data has created what we refer to as "Big Data". Without visual presentation such data is too big to understand. This is the big reason for visualization is emerging as a big market.

Combining several parameters through visualization could reveal something automated systems might ignore or don't pick up on. "The greatest value of a picture is when it forces us to notice what we never expected to see."[kilde på wiki] by John Tukey.

1.2.1 Characteristics

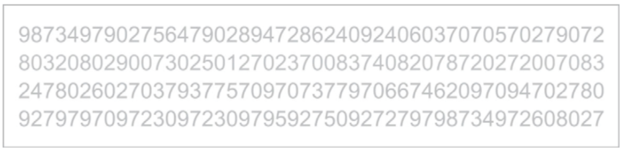
In his 1983 book The Visual Display of Quantitative Information, Edward Tufte defines characteristics any effective graphical representation should contain as:

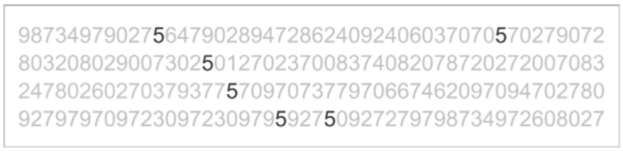
- show the data
- induce the viewer to think about the substance rather than about methodology, graphic design, the technology of graphic production or something else
- avoid distorting what the data has to say
- present many numbers in a small space
- make large data sets coherent
- encourage the eye to compare different pieces of data
- reveal the data at several levels of detail, from a broad overview to the fine structure
- serve a reasonably clear purpose: description, exploration, tabulation or decoration
- be closely integrated with the statistical and verbal descriptions of a data set.

1.2.2 Visual perception

In this paper the correlation between effective visual communication and how it is perceived upon human inspection is important. A humans ability to distinguish between differences in length, shape and color is referred to as "pre-attentive attributes".

A good example of this is imagining finding the number of a certain character in a series of characters. This requires significant time and effort, but if the character were to stand out by being a different size, color or orientation this could be done quickly trough pre-attentive processing. Good data visualization takes all of this into consideration and uses pre-attentive processing. In this simple example it is easy to see how pre attentive processing is used to distinguish how many occurrences of the number 5 is in a larger set of numbers.





1.2.3 Data presentation architecture

Data presentation architecture(DPA) has its purpose to identify, locate, manipulate, format and present data in such a way as to optimally communicate meaning and proffer knowledge[kilde]. This has become an important tool in Business Intelligence, the art of transforming raw data into something useful.

Objectives

DPA has two main objectives, which is the following:

– To use data to provide knowledge in the most efficient manner possible (minimize noise, complexity, and unnecessary data or detail given each audience's needs and roles)

– To use data to provide knowledge in the most effective manner possible (provide relevant, timely and complete data to each audience member in a clear and understandable manner that conveys important meaning, is actionable and can affect understanding, behaviour and decisions)

Scope

The actual work of DPA consist of:

– Creating effective delivery mechanisms

– Define relevant knowledge needed by each viewer

– Determine how often the data should be updated

– Determine how often and when the user needs to see the data

– Finding the right data

– Utilizing the best visualizations and presentation formats

1.3 D3.js

In this paper D3.js is chosen as the framework to create examples of effective data visualizations due to its dynamical and interactive properties. D3 stands for Data-Driven Documents, and is a Javascript library. D3.js allows users to bind arbitrary data to a Document Object Model. It uses widely implemented SVG, CSS and HTML5 standards. D3 is unique in the way it creates SVG objects from large datasets using simple D3.js functions to generate rich text/graphic charts and diagrams.

1.3.1 How does it work?

The W3C DOM API is often tiring to use. An example bit of code from[link/kilde] shows how one changes the text color of paragraph elements:

```

var paragraphs = document.getElementsByTagName("p");
for (var i = 0; i < paragraphs.length; i++) {
  var paragraph = paragraphs.item(i);
  paragraph.style.setProperty("color", "white", null);
}
```

In D3.js this could be solved trough one line of code:

```
d3.selectAll("p").style("color", "white");
```

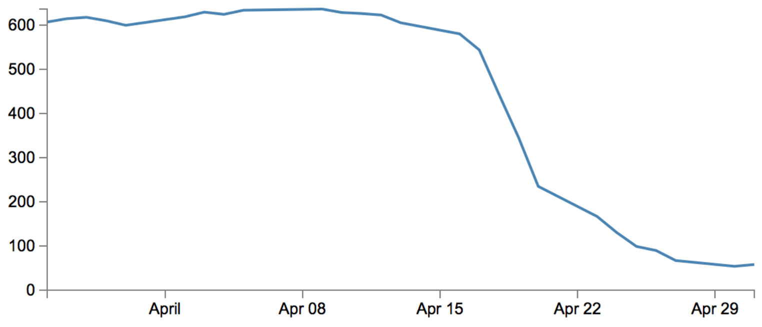
D3.js also possess dynamic properties which gives the user a powerful tool to create advanced graphics with a small amount of code.

This next snippet of code shows how the D3.js framework simply appends to an existing html object.

```
<!DOCTYPE html>
<meta charset="utf-8">
<style> /* set the CSS */

body { font: 12px Arial;}

path {
    stroke: steelblue;
    stroke-width: 2;
    fill: none;
}

.axis path,
.axis line {
    fill: none;
    stroke: grey;
    stroke-width: 1;
    shape-rendering: crispEdges;
}

</style>
<body>

<!-- load the d3.js library -->
<script src="http://d3js.org/d3.v3.min.js"></script>

<script>

// Set the dimensions of the canvas / graph
var margin = {top: 30, right: 20, bottom: 30, left: 50},
    width = 600 - margin.left - margin.right,
    height = 270 - margin.top - margin.bottom;

// Parse the date / time
var parseDate = d3.time.format("%d-%b-%y").parse;

// Set the ranges
var x = d3.time.scale().range([0, width]);
var y = d3.scale.linear().range([height, 0]);

// Define the axes
var xAxis = d3.svg.axis().scale(x)
    .orient("bottom").ticks(5);

var yAxis = d3.svg.axis().scale(y)
    .orient("left").ticks(5);

// Define the line
var valueline = d3.svg.line()
    .x(function(d) { return x(d.date); })
    .y(function(d) { return y(d.close); });

// Adds the svg canvas
var svg = d3.select("body")
    .append("svg")
        .attr("width", width + margin.left + margin.right)
        .attr("height", height + margin.top + margin.bottom)
    .append("g")
        .attr("transform",
              "translate(" + margin.left + "," + margin.top + ")");
```

```

// Get the data
d3.csv("data.csv", function(error, data) {
    data.forEach(function(d) {
        d.date = parseDate(d.date);
        d.close = +d.close;
    });

    // Scale the range of the data
    x.domain(d3.extent(data, function(d) { return d.date; }));
    y.domain([0, d3.max(data, function(d) { return d.close; })]);

    // Add the valueline path.
    svg.append("path")
        .attr("class", "line")
        .attr("d", valueline(data));

    // Add the X Axis
    svg.append("g")
        .attr("class", "x axis")
        .attr("transform", "translate(0," + height + ")")
        .call(xAxis);

    // Add the Y Axis
    svg.append("g")
        .attr("class", "y axis")
        .call(yAxis);

});

</script>
</body>
```

legg til kilde på koden her. This graph would be appended to the body element of the html and look like this:



In the code the dynamic properties are visible as the x- and y-axis change its parameters based on the input data.

Chapter 2 Research

2.1 Related work

In the last decade the importance of security against attacks on large computer systems has grown rapidly. In 2004, the ACM workshop on Visualization and data mining for computer security presented NVisionIP: netflow visualizations of system state for security situational awareness[kilde]. This was one of the first tools too visualize NetFlow data. The visualization was based on either number of bytes transmitted or the number of flows to or from the hosts on the network.

In [Kilde] they discuss the use of NVisionIP to combat different security concerns. Most of the same attacks covered in this paper are relevant today, only in today's massive amounts of data, they may be way more difficult to discover.

- **Worm infection**: One of the most basic security function one might uncover. Worms usually spread by probing for other hosts. Filtering out hosts transmitting a lot of Flows with a single destination port, one could easily see which machines are infected and should be taken offline.
- **Compromised systems**: If a host is compromised, the attacker might install malware that allows the attacker to control the machine. Following this an attacker might turn a host into a file server. By detecting large volumes of traffic on certain ports one might discover such an attack.
- **Misuse**: Misuse of computer networks in order with terms of use etc.. An example is detecting if certain users have abnormal high volumes of traffic, and by inspecting in more detail one can uncover if this trough one single application and not in accordance with the policies of the organization.
- **Port Scans**: When a large number of ports are used at a specific host it is easily identified by NVisionIP.

– **DoS**: Denial of Service Attacks will be visible trough spikes in traffic volume from the host attacking. If a host is attacked the same pattern is visible trough high volumes in receiving traffic. Thus peaks in traffic is not necessary an attack, but might be a result of a new release, or backup etc ..

2.2 Initial research

In section[om netflow] we see how the raw format of the NetFlow packets look. Comparing how understandable this format is comparing to a visual representation will be the main object of this paper. How much more effective is visualization compared to the raw format read by machines.

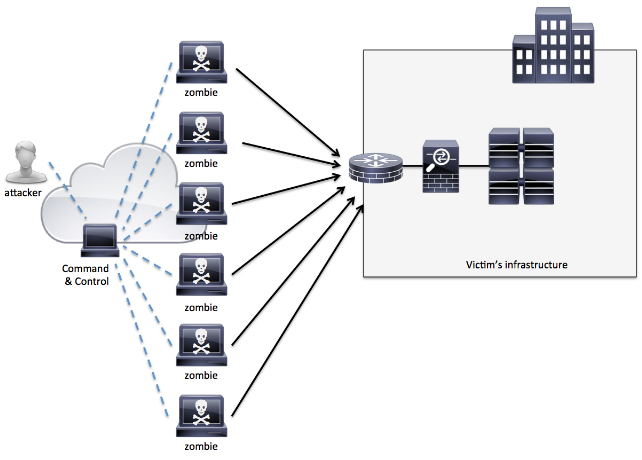
To understand this, experiments will determine how quickly one can distinguish an attack from both the raw format, and the visual representation.

This is were D3.js will come to great use. It can be used to quickly develop simple interactive graphs that can be used to test up against each other.

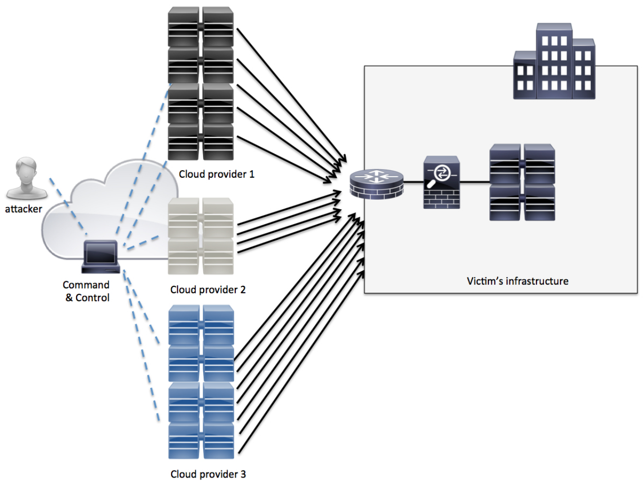
To be able to identify an DDoS attack, one can look at it from two angles. By finding someone whom is attacking, or someone whom is being attacked. In this case we will look at the second scenario. As mentioned earlier simply a peak in flows is not enough grounds to establish an actual attack. First of all, one will need to look for patterns of similar incidents, and what lies behind them.

2.3 Traits of a DDoS attack

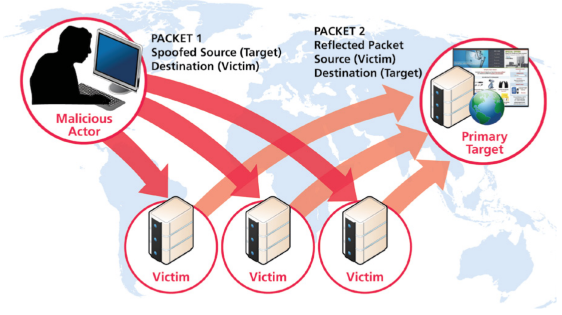
In a Distributed Denial of Service attack there are a large number of hosts performing the attack. In many cases a lot of them are not even aware they are a part on an attack. This is called a botnet, derived from the words robot and network. Using compromised systems, called zombies, gives the attacker control of a large enough amount of hosts to perform a volume-based DDoS attack.



Another new trend that has emerged is using large datacenters or cloud machines to launch these attacks. Either trough renting or compromising them. As cloud providers are offering such large amounts of computers, this new platform is not only great for legitimate use, but also cyber-criminals.



Distributed Reflection Denial of Service attacks is becoming more and more popular. DrDoS techniques usually involve mulitple victim host machines that unwillingly participate in a DDoS attack on the attackers primary target. Requests to the victim host machines are redirected, or re ected, from the victim hosts to the target. Anonymity is one advantage of the DrDoS attack method. In a DrDoS attack, the primary target appears to be directly attacked by the victim host servers, not the actual attacker. This approach is called spoo ng. Ampli cation is another advantage of the DrDoS attack method. By involving multiple victim servers, the attacker's initial request yields a response that is larger than what was sent, thus increasing the attack bandwidth.



2.3.1 Raw NetFlow format

```
router#show ip cache flow
IP packet size distribution (90784136 total packets):
  1-32   64   96 128 160 192 224 256 288 320 352 384 416 448 480
  .000 .698 .011 .001 .004 .005 .000 .004 .000 .000 .003 .000 .000 .000 .000
  512 544 576 1024 1536 2048 2560 3072 3584 4096 4608
  .000 .001 .256 .000 .010 .000 .000 .000 .000 .000 .000
IP Flow Switching Cache, 4456704 bytes
 1885 active, 63651 inactive, 59960004 added
 129803821 ager polls, 0 flow alloc failures
 Active flows timeout in 30 minutes
 Inactive flows timeout in 15 seconds
IP Sub Flow Cache, 402056 bytes
 0 active, 16384 inactive, 0 added, 0 added to flow
 0 alloc failures, 0 force free
 1 chunk, 1 chunk added
 last clearing of statistics never
Protocol         Total    Flows   Packets Bytes  Packets Active(Sec) Idle(Sec)
--------         Flows     /Sec     /Flow  /Pkt     /Sec     /Flow     /Flow
TCP-Telnet    11393421      2.8         1    48      3.1       0.0       1.4
TCP-FTP            236      0.0        12    66      0.0       1.8       4.8
TCP-FTPD            21      0.0     13726  1294      0.0      18.4       4.1
TCP-WWW          22282      0.0        21  1020      0.1       4.1       7.3
TCP-X              719      0.0         1    40      0.0       0.0       1.3
TCP-BGP              1      0.0         1    40      0.0       0.0      15.0
TCP-Frag         70399      0.0         1   688      0.0       0.0      22.7
TCP-other     47861004     11.8         1   211     18.9       0.0       1.3
UDP-DNS            582      0.0         4    73      0.0       3.4      15.4
UDP-NTP         287252      0.0         1    76      0.0       0.0      15.5
UDP-other       310347      0.0         2   230      0.1       0.6      15.9
ICMP             11674      0.0         3    61      0.0      19.8      15.5
IPv6INIP            15      0.0         1  1132      0.0       0.0      15.4
GRE                  4      0.0         1    48      0.0       0.0      15.3
Total:        59957957     14.8         1   196     22.5       0.0       1.5
SrcIf         SrcIPaddress    DstIf          DstIPaddress    Pr SrcP DstP  Pkts
Gi0/0         192.168.10.201  Gi0/1          192.168.60.102  06 0984 0050     1
Gi0/0         192.168.11.54   Gi0/1          192.168.60.158  06 0911 0035     3
Gi0/1         192.168.150.60  Gi0/0          10.89.16.226    06 0016 12CA     1
Gi0/0         192.168.10.17   Gi0/1          192.168.60.97   11 0B89 0050     1
Gi0/0         10.88.226.1     Gi0/1          192.168.202.22  11 007B 007B     1
Gi0/0         192.168.12.185  Gi0/1          192.168.60.239  11 0BD7 0050     1
Gi0/0         10.89.16.226    Gi0/1          192.168.150.60  06 12CA 0016     1
router#
```

In the preceding example, there are multiple flows for UDP port 80 (hex value 0050). In addition, there are also flows for TCP port 53 (hex value 0035) and TCP port 80 (hex value 0050).

The packets in these flows may be spoofed and may indicate an attempt to perform these attacks. It is advisable to compare the flows for TCP port 53 (hex value 0035) and TCP port 80 (hex value 0050) to normal baselines to aid in determining whether an attack is in progress.

Finne kommandolinjeversjon av et DDoS angrep

2.4 Using D3.js

Earlier in this paper it is mentioned that D3.js will be used to show examples of effective visualization of NetFlow data. It is assumed that the data has already been processed before it is made accessible to these examples.

2.4.1 Number of flows to a certain host and port

This example shows how a simple graph can recognize a DDoS attack trough giving the option to see the number of netflows on different hosts and ports.

Screenshot

To confirm that such a solution is more effective, it must be tested. By creating a simple tool to convey information visually and give people with no or little information on NetFlow a chance to compare a visual solution to the raw machine readable data, and find out how effective it actually is.

Todo list

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Screenshot 13