Juuso Järviö

CYBERGAME SECURE APPLICATION DELIVERY

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Lehtori Vesa Kankare

Tiivistelmä

Projektin tavoitteena oli luoda valmis tietoturvallinen ja optimoitu runko Cybergame-nimiselle verkkosovellukselle ottamalla käyttöön ADC-laitteen tietoturva ja optimointi ominaisuuksia. Sovellus ei ollut valmiina projektin aikana, joten toteutuksista luodun dokumentaation tuli olla kattava tulevaisuuden projekteja varten.

Projektissa tutkittiin tietoturva- ja optimointi -asetusten toteuttamista Cybergame-sovellukseen, joka on pelillistetty kyberturvallisuuden opetusalusta. Projektissa hyödynnetyt ADC-ominaisuudet toteutettiin F5 BIG-IP ADC-laitteilla, jotka olivat projektin olennaisimmat verkkolaitteet. Koska Cybergame-sovellus ei ollut valmis projektin aikana, testauksia varten luotiin WordPress-sovellus. Kali GNU/Linux -jakelupakettia käytettiin sen tarjoamien penetraatiotestaustyökalujen takia. Näitä työkaluja hyödynnettiin osan toteutuksista testaamiseen.

Tietoturvaominaisuudet, kuten application security policy, anomaliapohjainen DoS-suojaus, brute force -esto ja muutama pienempi ominaisuus konfiguroitiin projektissa. Optimointi-osa koostuu optimisoitujen TCP-profiilien ja TCP-multipleksoinnin, HTTP-pakkauksen ja Web Accelerationin konfiguroinnista. Projekti sisälsi myös jonkin verran ADC:n peruskonfigurointia ja työssä tarvittujen virtuaalikoneiden luomista.

Tietoturvallinen ja optimoitu runko luotiin Cybergamelle, mikä tarkoittaa, että projektin tavoitteisiin päästiin. Useita ominaisuuksia käsiteltiin projektissa, mutta osaa ei voitu käsitellä läpikotaisin. Tämä jättää tilaa mahdollisille tuleville projekteille Cybergamen ADC-laitteisiin liittyen. Projektissa luotua dokumentaatiota voidaan hyödyntää, kun tulevaisuudessa ominaisuuksia käyttöönotetaan valmiiseen Cybergame-sovellukseen.

Asiasanat

application delivery controller, verkkosovellusten tietoturva, verkkosovellusten optimointi, kyberturvallisuus

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Abstract

The aim of this project was to create a ready framework for a web application called Cybergame by implementing secure and optimized application delivery features. The application was not ready at the time of the project, so the implementations studied in the project were to be documented well for possible future projects.

In the project, the implementation of security and optimization features for an application called Cybergame, a cyber security teaching platform that makes use of gamification, were studied. The features used in the project were provided by F5 BIG-IP application delivery controllers, which were the main web devices in the project. As the Cybergame application was not ready at the time of the project, a WordPress testing application had to be created and used. Kali GNU/Linux distribution was also utilized for the penetration testing tools to test some of the implementations.

The security features such as the application security policy, the anomaly based DoS protection, the brute force block and some smaller application security features were configured. The optimization part consisted of the configuration of optimized TCP profiles and TCP multiplexing, HTTP Compression and Web Acceleration. The project also included the configuration of some basic ADC features and creation of required virtual machines

The objectives for the project were accomplished as a secure and optimized framework for the Cybergame was created. Several features were covered, but most of the features could not be studied thoroughly. That leaves room for the possible future projects related to the Cybergame ADCs. The documentation created in the project can be used in future when implementing the features into the finished Cybergame application.

Keywords

application delivery controller, web application security, web application optimization, cyber security

CONTENTS

ABBREVIATIONS

AAM	Application Acceleration Manager
AFM	Advanced Firewall Manager
ASM	Application Security Manager
ADC	Application Delivery Controller
AOM	Always On Management
DDoS	Distributed Denial of Service
DMZ	Demilitarized Zone
DoS	Denial of Service
EUD	End User Diagnostics
HMS	Host Management Subsystem
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
LTM	Local Traffic Manager
MOS	Maintenance Operating System
OSI	Open Systems Interconnection
SSL	Secure Sockets Layer
TCL	Tool Command Language
TCP	Transmission Control Protocol
TMM	Traffic Management Microkernel
TMOS	Traffic Management Operating System
TPS	Transaction Per Second
XSS	Cross-site scripting

1 INTRODUCTION

The objective of this project work was to study and implement the secure application delivery features of F5 BIG-IP ADC for an application called Cybergame, that will be explained more in detail in the next chapter. The Cybergame application was not complete at the time of the project, but a secure framework should be ready for the application once it is released. Some optimization features should also be implemented to increase the performance of the Cybergame. The features used in the project should all be documented and tested so that they can be implemented later to the Cybergame application.

The F5 BIG-IP devices that would provide the used features were located in CyberLab of the South-Eastern Finland University of Applied Sciences. The ADCs and some configurations had already been implemented into the CyberLab in previous projects. The configurations were tested by using tools found in Kali GNU/Linux distribution to find out the possible vulnerabilities and mitigations. A WordPress testing site would serve as a testing application since the Cybergame application was not available at the time of the project.

Some work related to the ADCs was already done in the CyberLab earlier. The devices were implemented into the CyberLab and some basic settings were configured in the thesis work of Antti Peltonen in early 2016 (Peltonen 2016). Later in 2016 Henri Kajova created a virtual laboratory, which makes use of the virtual versions of the BIG-IP. The thesis also covers some security configurations such as SSL offloading and DoS mitigation iRules. The virtual lab made by Kajova was also used in this project to get to know the BIG-IP devices. (Kajova 2016.)

2 CYBERGAME

A project called ”Cyber Security Expertise and Business Development” was started in May of 2015 in co-operation with KyUAS, LUT and Cursor Oy. The goal of the project was to create a hub called “CyberPros Academy” for the development of cyber security, piloting of cyber security services and studying of cyber threats and challenges. An innovation platform called “CyberLab” was to be built. The operating environment of CyberPros Academy hub includes a modern data center and a cyber security training class. The data center also known as CyberLab can be used to do penetration tests and vulnerability scans for example. (Rouhiainen & Kettunen 2015.)

The project is an innovative way to combine data center, gamification and cyber security expertise and research. The present deficit of skilled personnel in these areas is meant to be covered by creating a new research, knowledge, and innovation hub, which at the same time creates entrepreneurship and jobs in to the area. The cyber security expertise is delivered to a large crowd via a cyber security game. (Työ- ja elinkeinoministeriö 2014.)

The Cybergame is programmed in co-operation by the programming students of KyUAS and GoodLife Technologies company (Rouhiainen & Kettunen 2015). The game is going to be located in the CyberLab data center. It will consist of a virtualized KVM hypervisor platform called NEST, which contains all the virtual machines that are used in the Cybergame. Clientless remote desktop gateway called Guacamole is used to access the virtual machines. The back-end server will be running game features such as game logic and databases. The NEST and the backend are running on a VMware ESXi hypervisor. The front-end servers work as an interface into the Internet. All the traffic into the Cybergame network goes first through the Cybergame BIG-IP ADC. The ADC will handle web security, Denial-of-Service protection and SSL offloading. The second levels of network security are provided by the North-South Firewall. The basic design of the Cybergame network can be seen in figure 1.

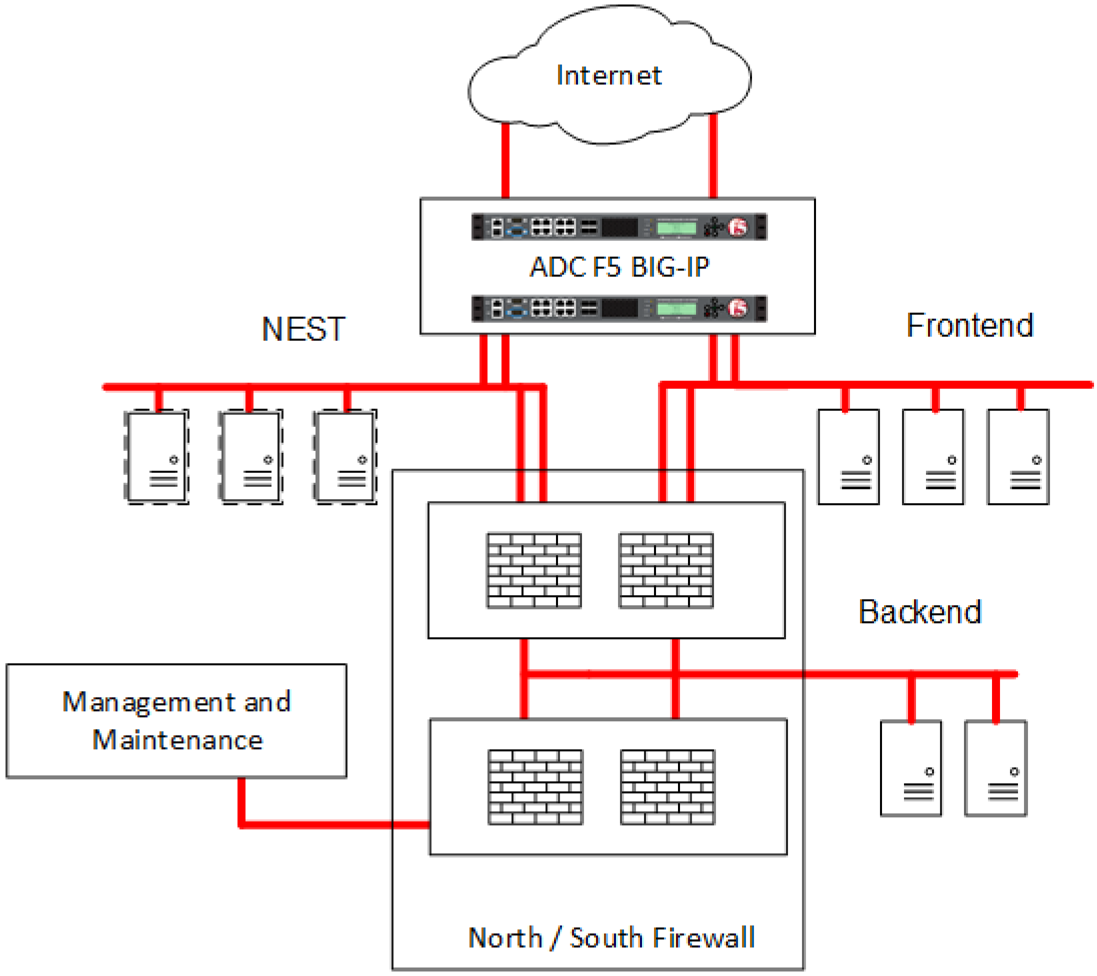


Figure 1. Cybergame network basic design.

3 APPLICATION DELIVERY CONTROLLER

Last decade the need for legacy load balancers to handle more advanced application related requirements increased, which started making ADCs popular. The purpose of an ADC is to increase the performance, security and availability of the web delivered applications. (Citrix 2016.) The application delivery controller is usually placed in the DMZ zone of a network, which typically locates between the firewall or the router and the application servers. An ADC helps sites to remove excess load from the servers by directing user traffic from multiple servers. On top of Layer 4 load balancing, ADCs can operate layer 7 for content switching and offload certain CPU-intensive tasks from the servers. (KEMP 2016.) The latest generations of ADCs can handle a large variety of additional functions such as rate shaping and serving as a web application firewall (F5 2016b).

3.1 ADC features

ADCs usually come in redundant High Availability configurations, which means that there are two devices of which one is an active device and another is in a standby. In case of failure in the active device, the standby device can become the new active device without any downtime. (KEMP 2016.)

Load balancing helps server cluster to distribute traffic to optimize utilization, and to increase the availability and responsiveness of the servers (Citrix 2016). There are many different Layer 4 IP-based methods provided by ADCs for distributing user traffic to servers. These Layer 4 methods can include Round Robin and Least Connection with Weighted versions of the two, Chained Failover with Fixed Weighting, and Server-Resource-Based load balancing. Weighting allows administrators to have better control of the traffic distribution. For example, if a higher performance server is added to the load balancing it can be appointed with a higher “weight”, so a larger amount of traffic will be allowed for it to handle. Layer 4 load balancing is sufficient for lower volumes of Internet traffic, but sometimes a more fine-tuned approach to the traffic distribution is needed. The fine-tuned approach can only be accomplished with Layer 7 content switching and other higher level load balancing methods. Content switching means the ability to load balance Layer 7 payload based user requests to the servers. For example, an URL with images may be pointed to a graphics server and shop can point to a transaction server. This provides more application flexibility and greater performance tuning. (KEMP 2016.) ADCs can also perform global server load balancing, which means the redirecting of traffic to a server cluster placed in another data center (Citrix 2016).

Application performance can be improved by many functions on an ADC, especially over mobile and high latency networks. ADCs can offload server intensive tasks, perform multiplexing, compression, and caching of high used static content. (Citrix 2016.) SSL offloading, for example, can be used to reduce the CPU usage of the application servers. By moving the SSL termination point to the ADC, the application servers are relieved from the CPU-heavy tasks of encrypting and decrypting traffic and setting up secured network connections, which greatly reduces the resources required by the application. (A10 2016.)

TCP multiplexing is another good way to improve the performance of applications. TCP multiplexing enables the device to reuse existing TCP connections, which removes the need for servers to open and close numerous TCP connections per second. TCP multiplexing improves the performance of the server and increases the capacity allowing the server to open more TCP connections for more users. (MacVittie 2008.)

HTTP compression and caching can both be used to reduce the load of the application servers. The number of HTTP object data transferred can be decreased with HTTP compression by utilizing GNU zip compression, which is available in every modern browser. The network bandwidth usage can be reduced without corruption of the content, which improves users' overall experience. If the task is offloaded to an ADC, it also saves the servers from the CPU-intensive task. Caching allows ADCs to store data from the servers in cache memory and deliver it quickly to the clients. This combined with HTTP compression means the ability to deliver pre-compressed data form the cache, rather than retrieving it from the servers every time. Caching can reduce the response times and boost transaction rates while freeing the servers to do other work. (KEMP 2016.)

Web security is an important feature of ADCs. The ADCs can recognize DDoS attacks and implement rate limiting measures such as throttling or rejecting the requests from a DDoS attack. They can also learn to detect malicious requests by analyzing the traffic to determine patterns for normal behavior. As ADCs, have converged load balancing and advanced layer 7 protection the application firewalls can even inspect packets for suspicious or malicious content. (Citrix 2016.) Typical network layer attacks such as flood attacks and connections per second overloading attacks can be easily defeated with features such as the full proxy architecture, purpose built hardware for the mitigation of DoS. Protocol validation is also used against invalid data and asymmetric attacks. (Holmes 2013.)

3.2 F5 Networks

F5 Networks is a US-based company headquartered in Seattle, Washington. F5 Networks specializes in application delivery networking. Its main product is the BIG-IP application delivery controller. (Crunchbase 2016.) F5 Networks was the market share leader in application delivery controllers with a 47% market share of the $2 billion market in 2015. Its largest competitors are Citrix, Radware and A10 Networks. (Lerner, Skorupa & Ciscato 2016.)

3.3 F5 BIG-IP

BIG-IP is a term for the compilation of hardware and software found in the ADC device made by F5. There is also a virtual edition available of the BIG-IP. The primary hardware components of the BIG-IP are Traffic Management Microkernel, Host Management Subsystem and Always On Management. The TMM includes several traffic processing hardware components such as a layer 2 switch module, dedicated SSL encryption or FIPS hardware and dedicated compression hardware. The HMS is responsible for system management and administration functions and runs a version of CentOS Linux. The HMS and the TMM share a single CPU and RAM memory. The AOM provides additional management of the HMS via a management processor and supporting functions for the TMM. The primary software components of the BIG-IP are also known as the Traffic Management Operating System or TMOS. Even though the TMOS name suggests that it is an operating system, it is a collection of firmware and operating systems, which run on BIG-IP and BIG-IP Virtual Edition. The TMOS includes TMM, HMS, AOM, MOS, EUD and feature modules like LTM. All the hardware components have software counterparts and have the same abbreviations. The TMM controls communications to and from the HMS. The LTM, iRules and other similar modules run within the TMM. The HMS runs a modified version of CentOS operating system and provides access to various management tools and interfaces such as the GUI configuration utility and an advanced shell. The AOM allows “lights out” power management and console access to the HMS. The MOS which is installed in an additional boot location is used for disk and file system maintenance. The EUD is a program that is used to perform BIG-IP hardware tests. (Jönsson & Iveson 2014, 21-25.)

F5 BIG-IP also includes a feature called iRules, which is based on the F5’s exclusive TMOS architecture. An iRule is a user created TCL program or script that is assigned to a virtual server in the BIG-IP. The scripts are run or triggered by a user or users doing events specified in the iRule. iRules can contain any number of commands and they can be programmed to do almost anything between the OSI layers 2 and 7, which leads to a great power and control over the network. (Iveson 2013, 18.)

All BIG-IP versions come default with either a Local Traffic Manager module or a BIG-IP DNS module, which has been known as Global Traffic Manager in the past. They both provide core functionalities for BIG-IP. Other modules can be activated on demand when a need for the feature is recognized, allowing customization of the BIG-IP. There are total of 13 modules available of which 10 are advanced BIG-IP feature modules and 3 feature modules for service providers. (F5 2016c.) There are two security modules available. Application Security Manager that protects web applications from attacks and the Advanced Firewall Manager, which is used to prevent network, SIP and DNS attacks (F5 2014b). In regards of application optimization, there is one important module, which is called Application Acceleration Manager (F5 2014a).

ASM is a web application firewall that secures web applications and protects them against vulnerabilities. The ASM can be used to develop different levels of security on layer 7. For example, The ASM can develop a security policy automatically based on the traffic patterns of the site. The policy can also be created manually or with a vulnerability assessment services. The security policies can protect web applications against many application layer threats such as SQL injection, buffer overflows, cross site scripting, cookie poisoning and many more. The ASM module can even protect the web infrastructure against layer 7 Denial-of-Service and zero-day threats. The ASM module also uses attack signatures to protect applications. By default, the BIG-IP ASM provides over two thousand signatures and more can be created manually. The signatures can detect different types of attacks against commonly used databases, applications and operating systems. (F5 2014b.) The ASM can also be used to detect DoS attacks using transaction based detection or latency based detection or both. The values of which the device uses to make the calculations can be changed manually. In the transaction based method, the average amount of requests per second to a certain URL or IP address is used. The latency based method uses the time the server takes to respond to the requests. If any of the intervals go beyond the selected percentage set in the DoS profile the ASM considers the system to be under attack. (F5 2013.) The IP intelligence feature of the ASM module also offers the ability to block connections based on their IP-address' geolocations or just their reputation around the Internet. The Data Guard can be used to block sensitive information such as credit card or social security numbers automatically from being displayed in a web browser. (Wagnon 2013.)

Advanced Firewall Manager, AFM is a module for F5 BIG-IP that offers defense against threats to network layers 3 and 4. The BIG-IP AFM module is a high-performance, stateful, full-proxy network security solution built especially for defeating high-capacity DDoS attacks against networks and network devices. The AFM can automatically mitigate the attacks, alert about an attack and adjust DDoS thresholds as traffic patterns change. The AFM includes high-volume logging controls to log the incoming traffic during a DDoS attack without it getting overwhelmed. IP-address blacklisting can also be enforced by reputation feeds offered by F5 networks and third parties. SSH and SSL connections are also controlled by the AFM. It can protect the SSH channel against data breaches and application attacks and inspect SSL sessions to terminate the connections of encrypted attacks. As most of the F5 feature modules the AFM can be combined with iRules to extend the ability to mitigate attacks and increase its functionality. (F5 2016a.)

Application Acceleration Manager is the main module for optimization features in the BIG-IP. With the native TMOS architecture, AAM makes it possible that web performance and WAN optimization can be combined with application delivery. The integration allows the enabling of technologies such as SSL offloading, HTTP compression, Web Acceleration and rate shaping. As other modules, the AAM can be combined with iRules. The AAM can also be used to optimize multitude of protocols delivered to heaps of different devices. (F5 2014a.)

4 WEB APPLICATION SECURITY

Web application security means the process of protecting websites and services against security threats that exploit vulnerabilities in the code of the application. Web applications are high-priority targets for attackers, because of complex source codes that increase the likelihood of vulnerabilities and code manipulation, ”high rewards” and the ease of execution as most attacks can be done automatically against many targets at a time. (Imperva 2017.)

Typical web application vulnerabilities include injection type attacks such as SQL injections, cross-site scripting, remote file inclusion and cross-site request forgery (Imperva 2017). The current trend in application security risks can be observed from lists such as the OWASP top 10 list. The list describes the current TOP 10 risks of application security. However, the attacks don’t end at the top 10 and there are many more application security risks. (OWASP 2013.)

4.1 Denial of Service

Denial of Service attacks are a powerful way to disrupt and deny availability of web services. DoS attacks are essentially done by flooding the target of the attack with a very large amount of legitimate traffic to render it inaccessible to other users. DoS attacks with multiple attackers are called Distributed Denial of Service attacks or DDoS. (Shakarian, Shakarian & Ruef 2013, 12-13.)

DoS attacks have moved up the OSI model starting from the network layer attacks from the early 90s into session attacks and then into application layer attacks. Network layer attacks are typically different flood type attacks. Session and presentation layers are attacked in session attacks, which consist of SSL and DNS attacks. Almost half of all the present attacks are done on the application layer. The detection of attacks becomes harder as the attacks go higher in the OSI model. (Holmes 2013.)

The network layer attacks are the traditional way of DDoS attacks. The purpose of the network layer attacks is to consume the bandwidth of the target and deny the service for users. These attacks include for example, ICMP flooding, SYN flooding and UDP flooding. These kinds of attacks are easy to mitigate nowadays and for this reason the attackers have started to move to other types of attacks. (Balandin, Andreev & Koucheryavy 2015, 275.) Against the most common network layer attack, the SYN flood, there are three different types of mitigation methods. Two of them are found on the typical network devices and servers and the third option, the use of SYN cookies is the best method and is found only on BIG-IP ADCs. (Holmes 2013.)

Session layer attacks use the OSI layers 5 and 6. They include attacks against SSL and DNS. With common firewalls, SSL attacks cannot be mitigated and the ability to defend against DNS attacks is limited. For both attacks the best defense is a high-performance, full-proxy functionality that can validate every DNS and SSL connection going through. Typical Session layer attacks against DNS servers include attacks such as DNS query floods and DNS NXDOMAIN floods, in which the attacker sends nonexistent records to the server and wastes the server’s resources. Against the SSL there are SSL floods and SSL renegotiation attacks. In the SSL flood attacks the attacker sends malicious or empty SSL connections to the server to exhaust its resources. The SSL renegotiation attacks exploit the asymmetric encryption ability of SSL. The SSL handshake requires 10 times more processing power on the server side than the client side, which means that in the worst case only one client is needed for the denial of service. (Holmes 2013.)

Application layer DDoS attacks, also known as layer 7 DDoS attacks are denial of service attacks where the attacker targets the application OSI layer. The attacks over use certain features and functions on a site to disturb or disable them. The application layer attacks are different from other types of attacks. (Kiyuna, Conyers 2015, 24.) Application layer attacks, unlike the network layer based DDoS attacks, can focus on draining other resources such as Sockets, CPU, memory or disk or I/O bandwidth instead of only exhausting the bandwidth (Balandin, Andreev & Koucheryavy 2015, 275). They can also be performed by using legitimate protocols and legitimate connections so signature based detection systems cannot detect them. The application DDoS attacks may also encrypt the data of the connections in the application layer, which makes the attackers hard to detect without violating their privacy. Anomaly-based detection is currently the best solution for the detection and prevention of application layer attacks. Anomaly based detection is based on typical user behavioral patterns and also allows the detection of, zero-day attacks. HTTP protocol attacks are the most popular on the application layer due to the popularity of the protocol and the amount of vulnerabilities it has. (Galinina, Balandin & Koucheryavy, 2016, 327)

Typical application layer attacks types include attacks, such as simple or recursive GET floods, POST floods, low bandwidth HTTP Attacks, Slow POST attacks and HasHDoS attacks. GET floods, which are one of the most popular application layer attacks request a static object or every object on a page that can be requested. POST floods work the same way as GET floods, but instead of a GET request, they send a POST that has a greater chance of using up the resources on the target server. Low bandwidth HTTP attacks such as the SlowLoris are hard to detect by regular means because they use a very low amount of bandwidth. SlowLoris and similar tools first learn the target's inactivity timeout timer and start feeding HTTP headers to the target in a very slow speed. A second before the timeout the SlowLoris sends a fake header to the server to keep the connection open. When the server has too many connections to open any new ones, the denial of service is achieved. Slow POST attacks work the same way as the SlowLoris, but instead of sending headers it starts an HTTP POST with the target and uploads data very slowly. HashDoS attacks work by sending a single POST message, which includes thousands of different variables to overwhelm the hashing function of the server. A single HashDoS POST message can disable a server for over an hour. (Holmes 2013.)

4.2 Web scraping bots

A Bot is an automated software program that runs tasks in the Internet. Typical bots perform simple, repetitive tasks at very high speeds. Almost half of all web traffic comes from bots and two thirds of the bot traffic is malicious. One of the ways that bots can cause harm to a site or an application is web scraping. Web scraping means the process of automatically collecting information from the Internet. The most common type of scraping aims to steal content from the web to use it elsewhere, which is called site scraping. The web scraping bots typically crawl the website and access the source code, parse it and remove the pieces they want and then post the content elsewhere on the Internet. Another, more advanced type of web scraping is the database scraping. It works like the site scraping bot, except it will ask the application to retrieve data from the database. (Saeed 2016.)

4.3 Brute force

Password-guessing attacks, also known as brute-force attacks are a common threat against web sites that require some kind of a user authentication. Trying every possible combination of characters systematically, until the right combination is called a brute force attack. A password can always be discovered by a brute force attack, but it can take a lot of time to find it out. The time to crack a password depends on its complexity. Brute-force attacks can also use dictionary words or slightly modified versions of dictionary words rather than random characters, because most people use dictionary based passwords. Brute-force attacks put user accounts into a risk and increase the site's traffic with unnecessary transactions. There are many tools for the brute-force attacks and most of them can utilize wordlists and proxy servers to try passwords from different IP-address with advanced rulesets. (OWASP 2016).

5 KALI GNU/LINUX

Kali Linux is a GNU/Linux distribution based on the Debian GNU/Linux distribution, which was first released in 2013. Kali focuses primarily on penetration testing and security auditing. By default, Kali contains hundreds of different tools for various information security tasks. Kali distribution was developed and funded by an information security company Offensive Security. (Offensive Security 2017b.)

The minimum system requirements for Kali are 8GB of hard disk space, 512MB of RAM memory and an Internet connection. Kali Linux can be downloaded and installed in a few different ways. The basic ISO image is available as 32-bit and 64-bit versions which can be installed via a CD or an USB. There is also a VM version of Kali for Virtual usage with ready installed VMware tools. Kali can also be running as a live CD, but it is not recommended as nothing can be saved. (Offensive Security 2017a.)

6 IMPLEMENTATION

The implementation part includes the implementation and testing of security and optimization features offered by the BIG-IP ADC. The implementations covered in this section should all be usable with the Cybergame application although some of the implementations need to be reconfigured or tweaked a bit when the Cybergame application is released. Some of the implementations were done to the test application located in www.cybergame.fi, which was at the time not available in the public Internet. To test most of the features a testing application with more features was required.

6.1 Basic configuration

At the start of the project, the ADCs had already been implemented into the CyberLab and some configurations had been made in previous thesis and project works (Kajova 2016; Peltonen 2016). The ADCs could be connected by local IP addresses 172.18.2.25 and 172.18.2.26. The required feature modules such as the ASM were installed and licensed. The VLANs, load balancing pools, nodes and the virtual servers for the required servers in the Cybergame had already been implemented so it was possible to access the Cybergame network through the ADC. The ADCs were set to an active/standby failover mode and the devices were in sync. The right certificates for the Cybergame.fi domain were added to the SSL profile in the ADC. The SSL was offloaded from the Cybergame servers into the ADC’s HTTPS virtual server for the cybergame.fi site.

Even though the basic configuration had already been implemented into the ADC, some changes to the base configuration needed to be made. The first problem that appeared was that it was only possible to connect to https://www.cybergame.fi, the non-secure http://www.cybergame.fi could not be accessed and no automatic redirection to the HTTPS was made. This type of implementation could cause unnecessary confusion in the future. A new virtual server for the HTTP traffic and HTTP to HTTPS redirection had to be created.

A new virtual server was created by going to the virtual server part of the menu in the ADC’s web interface, which was found under the Local Traffic module and then clicking the create new button. The settings for the virtual server were copied from the HTTPS version of the virtual server, except of the port number, which in this case was 80 instead of 443 and the load balancing address pool, which was left blank. The BIG-IP system default iRule called *"_sys_https_redirect"* was added to the new virtual server by going to the virtual server tab and clicking the resources button on the newly created virtual server. After implementing the iRule, traffic to the *http://www.cybergame.fi* was automatically redirected to *https://www.cybergame.fi.*

Another issue related to the basic configuration was that for some reason the clock settings of the devices were not in sync and the logging was behaving incorrectly. After a while it was noted that the Funet NTP servers used in the whole Cybergame were not working. A new NTP server had to be configured into the ADC. Luckily a new stratum 1 Symmetricom NTP server was just implemented into the laboratory in project lessons. The Funet addresses were replaced from the ADC's NTP configuration tab with the address of the new NTP server.

6.2 Creating the required virtual machines

After finding out the current state of the cybergame.fi site, it was seen that to test some of the features a new testing application was to be created. For example, there was no working login page on the current Cybergame site and to test the brute force blocking feature of the ADC one was required. WordPress was chosen for the application, because it is relatively easy to implement and contains required features for the testing application. The WordPress was installed into a Debian GNU/Linux operating system. As the Cybergame network was at the time not connected to the Internet, the installation of the operating system and the WordPress had to be done locally. The Debian was installed on a local VMWare workstation and the required LAMP package and updates were installed. The WordPress was also downloaded into a directory, but not yet installed. The Virtual machine was then uploaded in the Cybergame VMWare ESXi server and placed into the frontend VLAN, where the cybergame.fi site was also located. After the server was added to the frontend the WordPress was extracted and installed on the server. A local IP-address from the frontend VLAN was added to the eth0 interface and a virtual server was created for the site from the ADC. After that, an address from the "INTERNET" pool of the ADC was added for the site. The

INTERNET address pool includes some public addresses assigned to the CyberLab, but as the whole CyberLab was not connected to the Internet they could be used without harm. The site was then accessible from the address 193.167.58.249.

To test the implemented security settings a Kali Linux virtual machine was also required. The Kali Linux was installed as a local installation. The Kali was set to use the network card of the local computer, because it needed to connect to the Cybergame network from the “public” side and not from the “inside”. The updates were the only change done to the Kali at this time, as they were required to install open-vm-tools and new security testing tools. The address of the new testing site was confirmed accessible from the Kali, which meant that security testing could be done.

6.3 Configuring security

The Configuring of the web security settings was the main part of this thesis. The configuration of the security part includes the configuration of security features that could be usable with the Cybergame application. The security settings were configured using the template site located at www.cybergame.fi and the WordPress test site created earlier. The Application layer security settings used were offered by the ASM module and the basic layer 3-4 protection settings were featured by the AFM module.

6.3.1 Application security policy

The ASM application security policy offered the basic defense against the application vulnerabilities and attacks. As the application security policy uses signatures as one of the mitigation methods the signatures had to be up to date. The BIG-IP system comes default with many application attack signatures and more are coming as updates every now and then. As the signatures could be important to application security, the signature updates were made automatic so that the device always has the newest signatures. The update frequency settings could be found by navigating to *Security > Options > Application Security > Attack Signatures.* On top of the screen, there was a selection for *Scheduled* or *Manual* update mode. The mode was changed to Scheduled. One step below the mode selection is the update interval menu, which could be set to daily, weekly or monthly. The update interval was set to a daily frequency. Few steps below the interval setup was a checkbox for auto applying new signature configurations after an update, which was also checked. On the very bottom of the screen, the status for the update attempts could be seen. The system would now check and apply new updates daily. A successful update with signature details can be seen in figure 2.

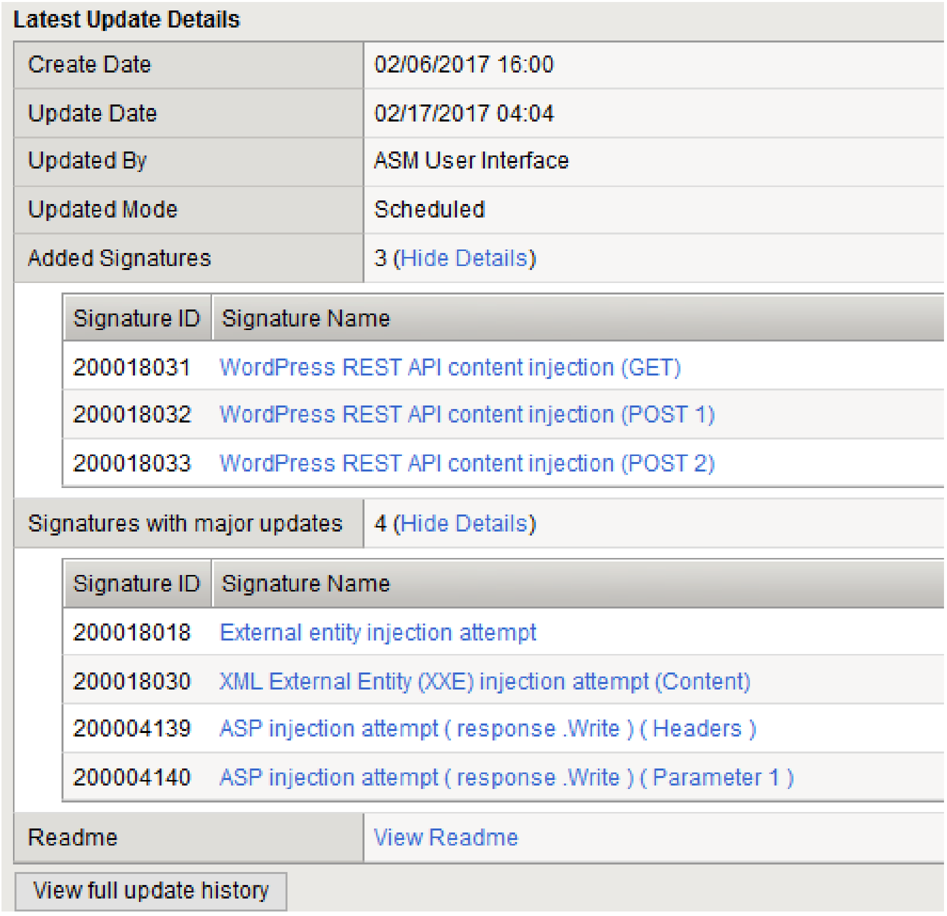


Figure 2. Successful update with signature details.

Before the implementation of an application security policy, to log application security events, a logging profile with application security logging enabled had to be created. The logging profile was created by going to *Security > Event Logs > Logging Profiles* and clicking new. All of the checkboxes, except for the network firewall were checked. The log profile was then enabled from the virtual server's security policies setting menu. After the logging was enabled, a new application security policy was created. The creation of security policy was also required for many of the ASM application security features. By navigating to *Security* > *Application Security* > *Security Policies* and clicking the *create* button a new policy was created. The association of a policy required a working virtual server with basic configurations such as addressing done. The associated virtual server had also to have an HTTP profile set and could not be associated with a *Local Traffic* policy. Two security policies were done, one for the Cybergame virtual server and one for the WordPress site for testing. However, the policies did not differ much from each other. From the scenario selection, *Existing virtual server* was chosen. On the next screen a selection for the protocol used and the virtual server could be seen. In the case of the Cybergame server the HTTPS only protocol was chosen, as Cybergame only works on HTTPS and for the WordPress test site the regular HTTP was selected. On the next page, there were four choices for building the security policy. The choices were automatic, manual or with templates, policy for XML and web services manually and the creation of policy by using a third-party tool. The automatic policy creation was chosen to test the application security policy creation. It is possible to edit the policy manually after it has been implemented. After selecting the automatic creation more policy settings were asked. From the *Application Language* list, *Auto detect* was selected. On the next screen, the attack signatures could be selected. There are three different categories of signatures ready selected which are *General Database*, *System Independent* and *Various Systems*. More needed signatures can and should be added later when more about the Cybergame system is known. As for the WordPress site, the used services were known so MySQL, Apache and PHP signatures could be selected. The configuration of automatic policy building was next. There were three levels of policy building to select. *Fundamental* is the most basic one, *Enhanced* is the middle ground and *Comprehensive* is the one with most policies. The learning speed of the policy could also be adjusted from the menu. The faster the learning speed, the bigger the chance to add false entities. The comprehensive policy type was selected because it gives the most features. The policy builder speed was set to the fast level. To speed up the learning of the policy, some trusted addresses of clients were added to the settings of the security policy, as the policy learns faster from the trusted traffic. For the future Cybergame application a building type should be chosen, depending on the needed elements and the extent of the policy. According to F5 the use of the default policy building settings is suggested and the basic settings are sufficient for most applications, as they also require less work. (F5 2014b).

Real Traffic Policy Builder®	Detecting Language
General Progress	

Policy Elements Learned

Entity	Elements
File Types	0
URLs	0
Parameters	0
Cookies	0
Redirection Domains	0

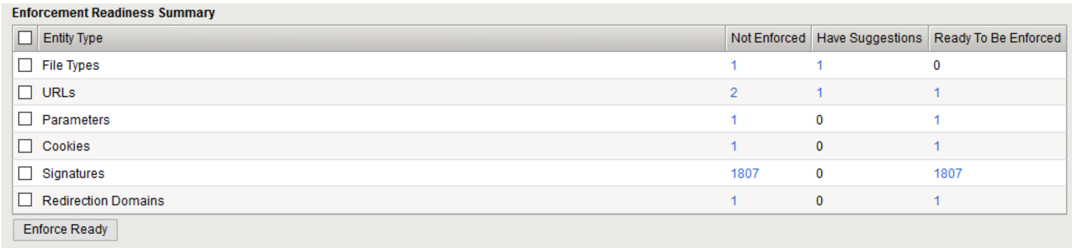
Figure 3. Automatic Policy builder progression.

After all the settings were selected the policy builder went to the status page, which is seen in figure 3, it shows the current learned policy elements and the general progress of the policy creation. As the policy learns from the traffic of the application, the progress bar will not go to the end until the policy has collected enough traffic. The settings were saved by clicking the apply policy from the top right corner. As the policy was associated with a virtual server, all the web application traffic in the virtual server will be examined by the ASM and used for the policy building (F5 2014b). The status page of the policy builder could be found by going to *Security > Application Security > Policy Building > Status (Automatic).* The learned elements that were chosen in the policy building level selection could also be observed from the status page. The page also shows the amount of traffic certain elements on the website have gotten. For example, the parameters and the traffic for the WordPress can be seen in figure 4.

Parameters in staging	Parameter level	Total Traffic (Trusted)	Sessions (Trusted)	IPs (Trusted)	Period (Trusted)	Action
_wpcf7	(Global)	0 / 2	0 / 2	0 / 1	0 / 1 hours, 12 minutes	Enforce
_wpcf7_locale	(Global)	0 / 2	0 / 2	0 / 1	0 / 1 hours, 12 minutes	Enforce
_wpcf7_unit_tag	(Global)	0 / 2	0 / 2	0 / 1	0 / 1 hours, 12 minutes	Enforce
_wpcf7_version	(Global)	0 / 2	0 / 2	0 / 1	0 / 1 hours, 12 minutes	Enforce
rememberme	[HTT....php	Rule Satisfied	1 / 2	Rule Satisfied	0 / 1 hours, 12 minutes	Enforce
your-email	(Global)	0 / 2	0 / 2	0 / 1	0 / 1 hours, 12 minutes	Enforce
your-message	(Global)	0 / 2	0 / 2	0 / 1	0 / 1 hours, 12 minutes	Enforce
your-name	(Global)	0 / 2	0 / 2	0 / 1	0 / 1 hours, 12 minutes	Enforce
your-subject	(Global)	0 / 2	0 / 2	0 / 1	0 / 1 hours, 12 minutes	Enforce

Figure 4. Parameters and traffic in the security policy.

When the policy creation has gotten enough traffic to learn all the needed policy elements for the application, the signatures were taken out of staging state. In the staging mode, the signatures are applied to the application traffic, but the blocking flag is not applied to the requests that trigger the events (F5 2014b). That was done by navigating to *Security > Application Security > Attack Signatures > Attack Signature Configuration* and unchecking the Signature Staging box. The signatures and other elements that were ready to be enforced could also be studied and enforced at *Security > Application Security > Policy Building > Enforcement Readiness*, as seen on figure 5.



Enforcement Readiness Summary

Entity Type	Not Enforced	Have Suggestions	Ready To Be Enforced
File Types	1	1	0
URLs	2	1	1
Parameters	1	0	1
Cookies	1	0	1
Signatures	1807	0	1807
Redirection Domains	1	0	1

Enforce Ready

Figure 5. Enforcement readiness of the policy elements.

When enough traffic was given to certain objects on the site, the system listed all the learned parameters and URLs of the site. The page could be, for example, viewed in a tree mode to easily see what URLs and parameters the ASM policy had learned. The tree view of the Cybergame.fi can be seen in figure 6.

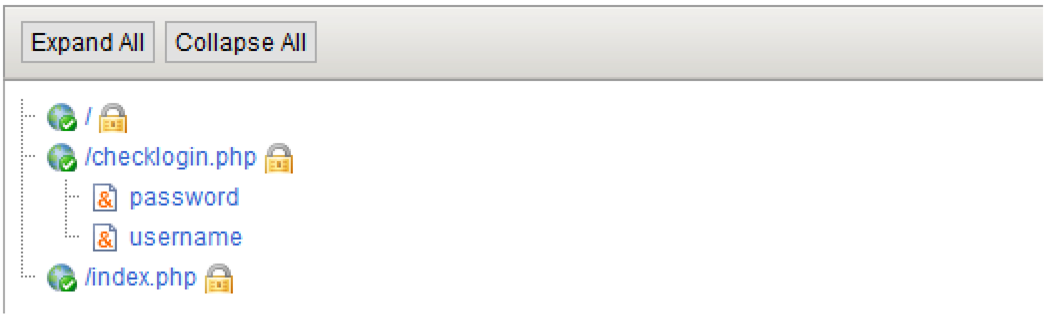


Figure 6. ASM tree view.

The ASM policy also needed to be synced into the other device in the Sync-Failover device group as the other configurations are. By going to *Security > Options > Application Security > Synchronization* and selecting the right failover group from the list, the system synced the ASM configurations in similar way as it did to other configurations as shown in figure 7.

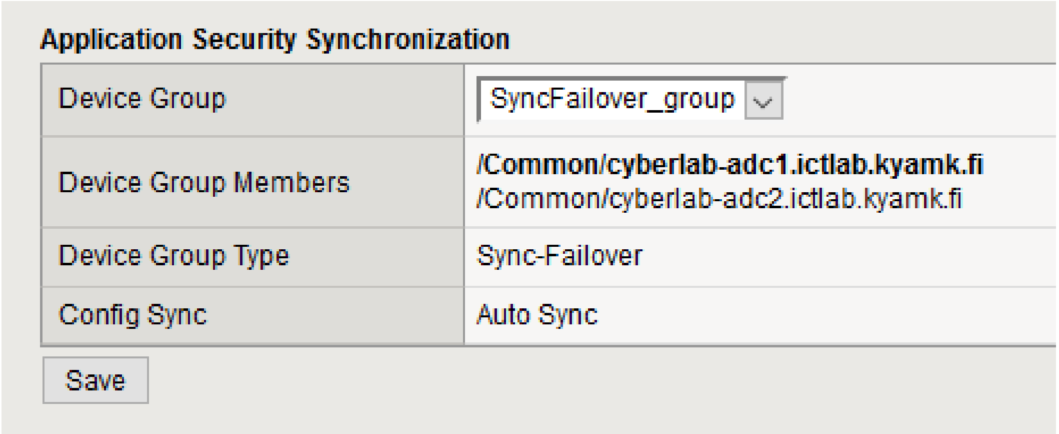


Figure 7. ASM sync.

When the ASM policy was set to active and started noticing violations, it would report them to the event logs. The violations list in the policy's "blocking" section determined how the system would process the triggered violations. The blocking section could be found by going to *Security > Application Security > Blocking*. The enforcement mode of the Violations List could be either set to transparent or blocking mode. In the blocking mode, the violations would be reported to logs and blocked. In the transparent mode, the traffic wouldn't be blocked even if it causes violations, which is why the transparent mode was suggested to be used when creating an application security policy. To test the violations, the enforcement mode was set to blocking mode. The blocking section also included a large list of different violations. There were six different violations categories, which include RFC, Access, Length, Input, Cookie and Negative security violations. Each violation could be configured with three different flags. The *learn* flag allowed the system to log the illegal request and create a learning suggestion of it. The alarm flag logged the request and alarms about the request. In the blocking mode, the violation was logged and blocked, the enforcement mode had to be set to blocking mode for the block flag to work. The violations list gave more information about the violations when the "i" icon next to a violation was clicked.

When the WordPress site's policy was ready, it was tested. To test the violations, some flags were set manually to the violations list. The violations found by the system could be observed from *Security > Application > Requests*. Both illegal and legal requests could be viewed from the logs depending on the log configurations. Vulnerability on an application was also needed to test ASM policy's ability to defend against application vulnerability exploits. A program called WPScan was ran from the Kali Linux virtual machine to determine if WordPress had any vulnerabilities to exploit. The following command was written to the Kali terminal to scan the WordPress site for vulnerabilities.

```
wpscan -u 193.167.58.249
```

The installed version of WordPress had a few vulnerabilities including some XSS vulnerabilities, of which one was chosen. According to Montpas, the vulnerability is included in the WordPress' youtube embed shortcode and it allowed attackers to deface posts on sites and store malicious JavaScript in them (Montpas 2017). The following code was then entered to WordPress site as a post from an administrator user.

```
[embed
src='https://youtube.com/embed/12345\x3csvgonload=alert(1)\x3
e'][/embed]
```

(Montpas 2017).

When the code was posted, the results could be instantly seen form the ADC's logs. The policy found many violations from the HTTP request, of which one was *Attack signature detected.* The blocked request is shown in figure 8. If a client is blocked by the ASM policy, the following message as in figure 9 will appear on the web browser of the client.

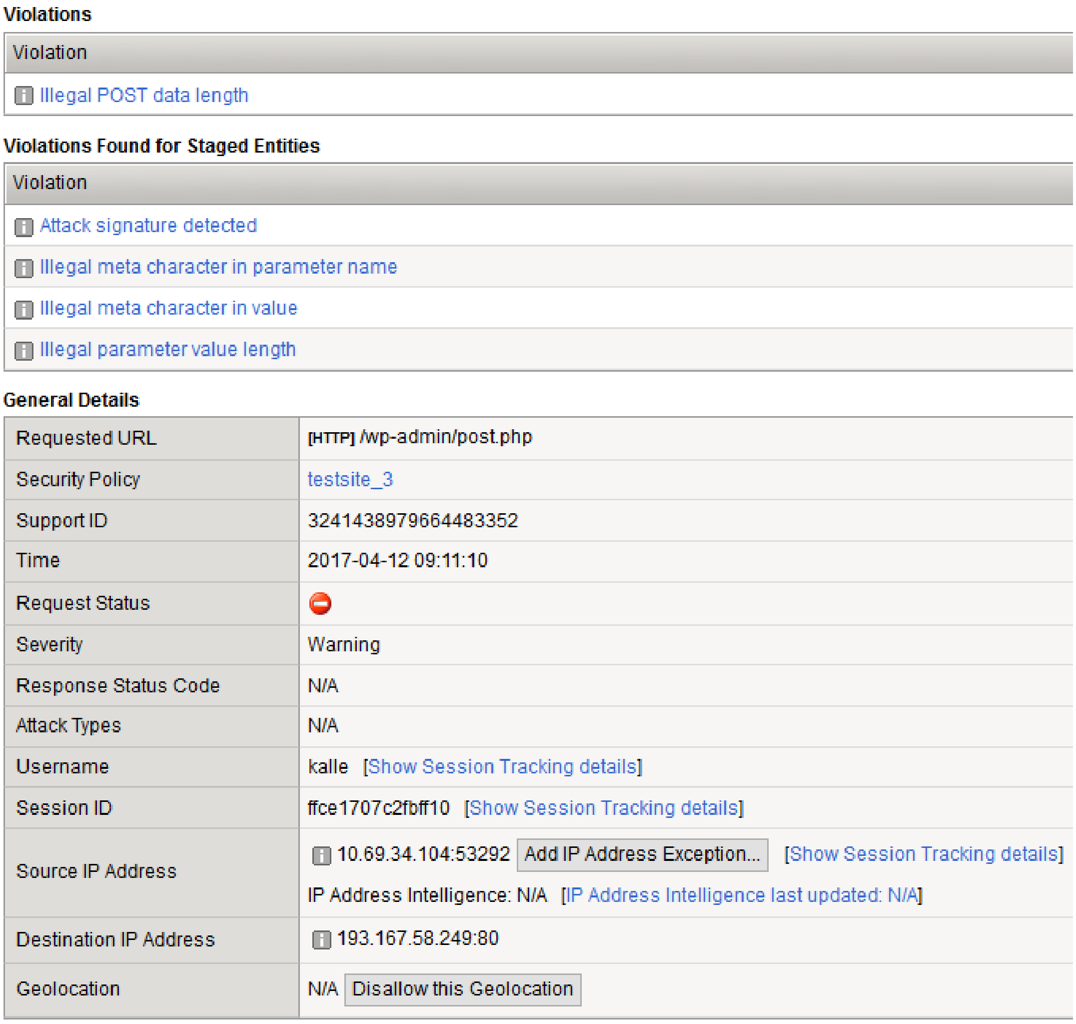


Figure 1. ASM request violation details.

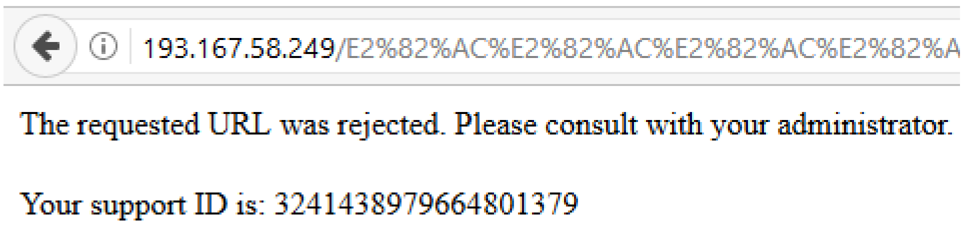


Figure 2. ASM error message shown to the client.

When the detected Attack signature was looked closer, it was seen that there are three signatures found on the XSS code posted to WordPress. The signatures can be seen in figure 10. The violations and details of the attack signatures could also be observed in more detail as can be seen from figure 11. From the outcome, it could be determined that the application security policy could be used to mitigate application vulnerabilities and exploits, such as XSS and other attacks that were listed in the OWASP top 10 automatically.

Attack signature detected violation details

Signature Name	Signature ID	Learn	Alarm	Block	Details
src http: (Parameter)	200001139	Yes	Yes	Yes	View details...
onload (Parameter)	200001037	Yes	Yes	Yes	View details...
alert() (Parameter)	200001088	Yes	Yes	Yes	View details...

Figure 3. Attack signatures found.

Context Details for Attack Signature 200001139	
Context	Parameter
Parameter Level	Global
Wildcard Parameter Name	*
Actual Parameter Name	content
Parameter Value	[embed 0x20 src='https://youtube.com/embed/12345\x3csvg 0x20 onload=alert(1)\x3e'][/embed]
Detected Keywords	content=[embed 0x20 src='https: //youtube.com/embed/12345\x3csvg 0x20 onload=alert(1)\x3e'][/embed]

Figure 4. Details on the signatures.

The combination of BIG-IP application security policy and the guacamole application had also to be tested, as the Guacamole will be in an important part in the Cybergame. Cybergame's ESXi hypervisor contained an early version of a Kali Linux virtual machine that could be used in the NEST. The virtual machine was chosen for the testing. The settings of the virtual machine were configured so that its traffic would go through the ADC's NEST virtual server and it would appear as a public IP address as was done in the virtual machine creation chapter earlier. As the Guacamole uses the port 8080 by default, an iRule that redirects traffic to the port 8080 had to be added to the NEST's virtual server on the ADC. The virtual machine was then available from IP-address 193.167.58.247. To access the virtual machine using Guacamole, "/guacamole" had to be entered after the address. After entering to the virtual machine, the machine worked well even though it was somewhat slow. The cause of the slowness could have been the old version of the virtual machine or because of the traffic going through the ADC. Next was the automatic creation of application security policy using the policy builder. It was done the same way as earlier in this chapter. When the policy builder was set on and traffic was sent to the Guacamole, the policy started learning elements. The learning of the Guacamole's elements went on well except for the parameters section, which started showing some odd values. After a few clicks on the Guacamole virtual machine, the parameter learning logs had large amounts of the values. Some research had to be done, because it seemed that the policy builder was not working right. The values can be seen in figure 12.

3.key,5.65513,1.1;	[HTTP] /guacamole /tunnel	1 / 2	Rule Satisfied	Rule Satisfied	Accept
3.key,5.65515,1.0;	[HTTP] /guacamole /tunnel	1 / 2	Rule Satisfied	Rule Satisfied	Accept
3.key,5.65515,1.1;	[HTTP] /guacamole /tunnel	1 / 2	Rule Satisfied	Rule Satisfied	Accept
4.sync,13.149327*; **(*)**	[HTTP] /guacamole /tunnel	1 / 2	Rule Satisfied	Rule Satisfied	Accept
4.sync,13.1493275813200;5.mouse,3.741,3....1.0;	[HTTP] /guacamole /tunnel	1 / 2	Rule Satisfied	Rule Satisfied	Accept
4.sync,13.1493275814966;	[HTTP] /guacamole /tunnel	1 / 2	Rule Satisfied	Rule Satisfied	Accept
4.sync,13.1493275815122;5.mouse,3.638,3....1.4;	[HTTP] /guacamole /tunnel	1 / 2	Rule Satisfied	Rule Satisfied	Accept
4.sync,13.1493275815340;	[HTTP] /guacamole /tunnel	1 / 2	Rule Satisfied	Rule Satisfied	Accept

Total Entries: **1636** Page 3 of 82

Figure 12. Example of The Guacamole protocol values and the amounts.

After studying the Guacamole documentation, it was found that the values were Guacamole protocol instruction messages. The messages are send from the client to server and from server to client. (Apache s.a.a.) For example the key values that can be seen in figure 12, are sent every time a key is pressed or released in the Guacamole virtual machine (Apache s.a.b). At the current state, the automatic security policy creation can't be used with the Cybergame Guacamole virtual machines. The combination of Guacamole and application security policy need to be studied more.

6.3.2 Anomaly based detection

The AFM module offers automatic mitigations of layer 4 DoS attacks, however against layer 7 DoS attacks some more advanced mitigation methods were needed. The Anomaly based detection, which was featured by ASM could be implemented against layer 7 attacks. The anomaly based detection is essential against for example HTTP-GET attacks. The anomaly based detection could be configured against TPS based anomalies and the latency based anomalies. The TPS based anomaly was meant for the client side and the latency based anomaly for the server side protection. The DoS protection could be set to either transparent or blocking mode. The DoS protection settings could be found by going to *Security > DoS protection*. In the DoS protection tab, the create button was clicked and the new profile was named.

Next the application security check box was selected and more options appeared. The TPS-based anomaly was set to the blocking operation mode and all the prevention policies were checked. The TPS values and the prevention duration were left to default. The TPS-based anomaly configuration is shown in figure 13.

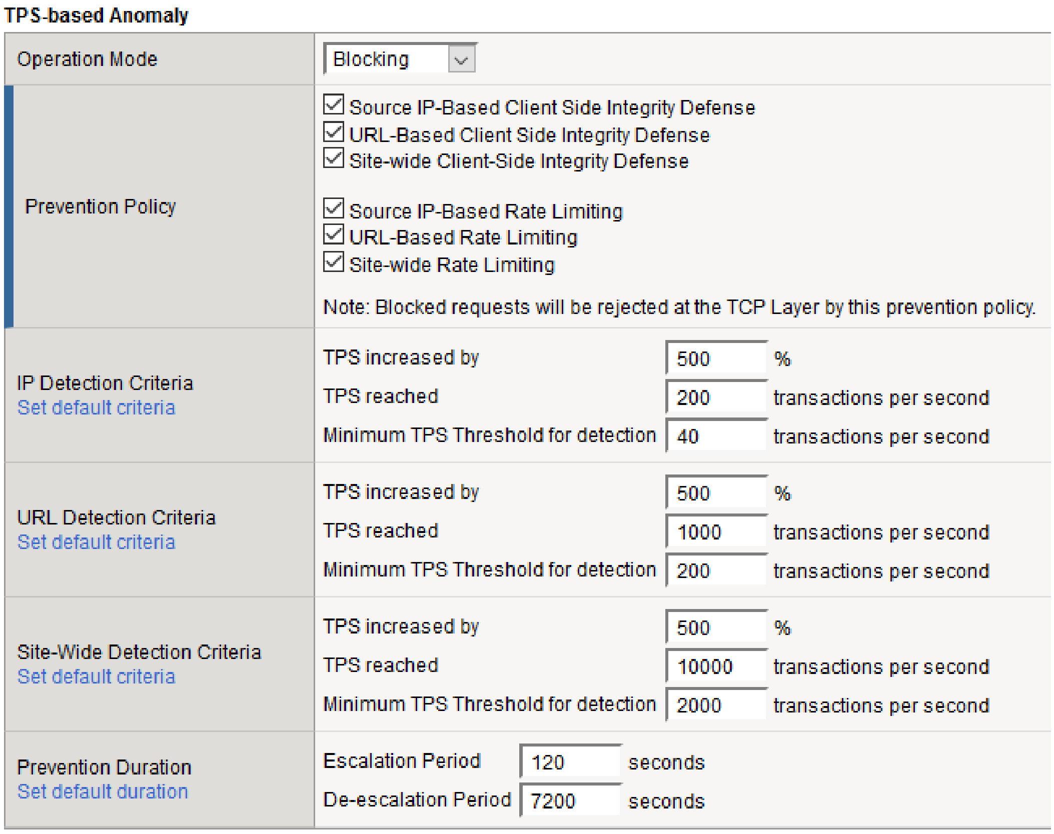


Figure 13. TPS-based anomaly configuration.

The TPS-based detection would now calculate the average TPS values and look for anomalies. After the TPS-based detection, the latency-based detection was to be implemented. The operation mode was again set to the blocking mode. The detection criteria were set to default settings and all the prevention policies were checked. The TPS criteria and the prevention settings were again left to default. The settings for the latency-based detection can be observed from figure 14. The latency-based detection would now look for anomalies in URL-latency, minutely and hourly.

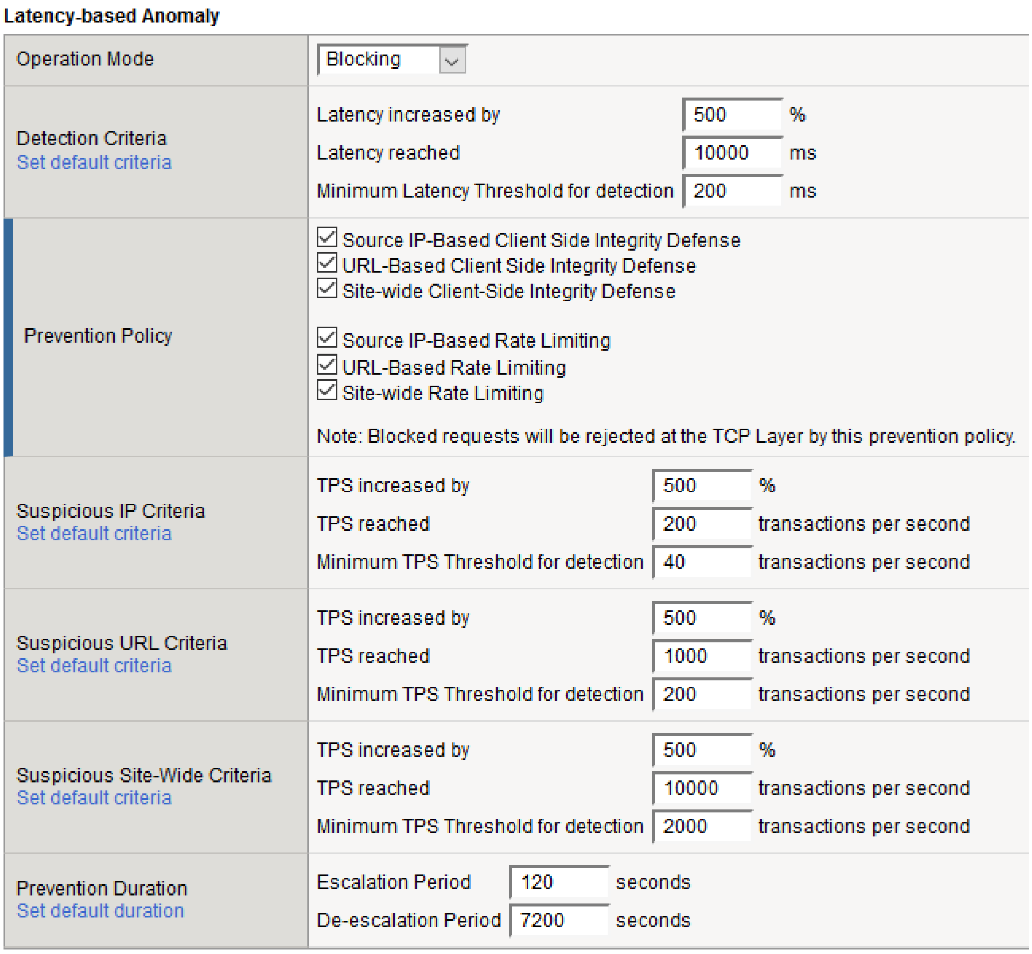


Figure 5. Latency based anomaly configuration.

In the settings there was also feature called Heavy URL Protection and under that Automatic detection, which both were checked. Heavy URLs can also be added to the protection list or a whitelist of the DoS profile manually when some of them are known. Lastly the DoS profile was set to record traffic during attacks by checking the checkbox form the end of the page. The DoS profile was then saved by clicking the update button and was implemented into a virtual server. The right virtual server settings were opened, then from the security menu the policies tab was opened. Using the advanced configuration mode, the DoS protection profile was enabled and the created profile was associated with the virtual server. The statistics for the DoS protection profile could be found by navigating to *Security > Event Logs* or *Reporting > DoS > Application.* The anomaly based detection should now block and report anomalies it notices in the network traffic to the logs.

To test the anomaly based detection, a layer 7 DoS tool was used. A tool named slowhttptest was chosen for the process. The tool was downloaded for the Kali Linux from the APT-repositories. The tool could be used by simply typing slowhttptest to the Linux terminal and then adding parameters. The slowhttptest tool had four different attack modes to be used, which could be changed with lettered parameters. “-H” mode is for slow headers also known as Slowloris, “-B” mode for slow body attack, “-R” for range attack and –X for slow read. According to F5 the ASM anomaly detection should be able to recognize all of the above except for the Slowloris, which will be analyzed later in the work (Holmes 2012). The three mitigatable attacks were tested by using command:

slowhttptest –R –c 5000 –u http://193.167.58.249

The first letter after the “slowhttptest” determines the mode, the –c defines the amount of connections used and after the –u the tested URL should be added. Other parameters could also be added, but they were not necessary for these tests. After doing some testing with the command a problem was noted. The anomaly based detection did not notice the attacks, even though the site went down with some of the modes used. Following the testing, the TPS and the latency values for the detection of the DoS attacks had to be taken down by a very big margin for both the TPS and latency based detection from the settings of the DoS profile. After modifying the profiles, the tests were done again. The results popped instantly into the application DoS logs, which show the starting and ending times of the attacks and the detection method used. The results can be seen in figure 15. When the anomaly based detection is implemented into the real Cybergame application, the profiles should be tuned again for the profiles to correspond the traffic of the site.

Time	Event	Detection Mode	Mitigation	Host	TPS/Latency	Attack ID
2017-03-10 08:24:37	Attack ended	DOS L7 attack	URL-Based Client Side Integrity Defense	172.18.2.25	0 tps	141148842
2017-03-10 08:23:10	Change mitigation	DOS L7 attack	URL-Based Client Side Integrity Defense	172.18.2.25	0 tps	141148842
2017-03-10 08:21:02	Attack started	DOS L7 attack	Source IP-Based Client Side Integrity Defense	172.18.2.25	8 tps	141148842
2017-03-10 08:18:59	Attack ended	DOS L7 attack	Source IP-Based Client Side Integrity Defense	172.18.2.25	0 ms	141148841
2017-03-10 08:16:03	Attack started	DOS L7 attack	Source IP-Based Client Side Integrity Defense	172.18.2.25	1076 ms	141148841
2017-03-10 07:59:24	Attack ended	DOS L7 attack	Source IP-Based Rate Limiting	172.18.2.25	0 tps	141148840
2017-03-10 07:55:44	Attack started	DOS L7 attack	Source IP-Based Rate Limiting	172.18.2.25	5 tps	141148840
2017-03-10 07:46:35	Attack ended	DOS L7 attack	Transparent	172.18.2.25	0 tps	141148839
2017-03-10 07:44:38	Attack started	DOS L7 attack	Transparent	172.18.2.25	10 tps	141148839

Figure 15. ASM anomaly detection logs.

6.3.3 Web scraping

There were a few available features offered by the ASM module to counter malicious bots. According to F5 the caching should be disabled when mitigating web scraping bots, as the cached content won’t be protected from the bots. The clients that use the application need also to have JavaScript enabled and support cookies for the anomaly detection to work. (F5 2014b). At first basic bot detection was implemented by going to *Security > Application Security > Anomaly Detection > Web Scraping.* The system could be set to alarm or alarm and block the bots in case of malicious bots appearing. The alarm setting was chosen in all cases. When the Bot Detection was enabled, some selections appeared at the bottom of the screen. The settings were left to default. The bot detection setting determines if the client is a human or a bot by limiting the page changes allowed during a certain time as seen in figure 16.

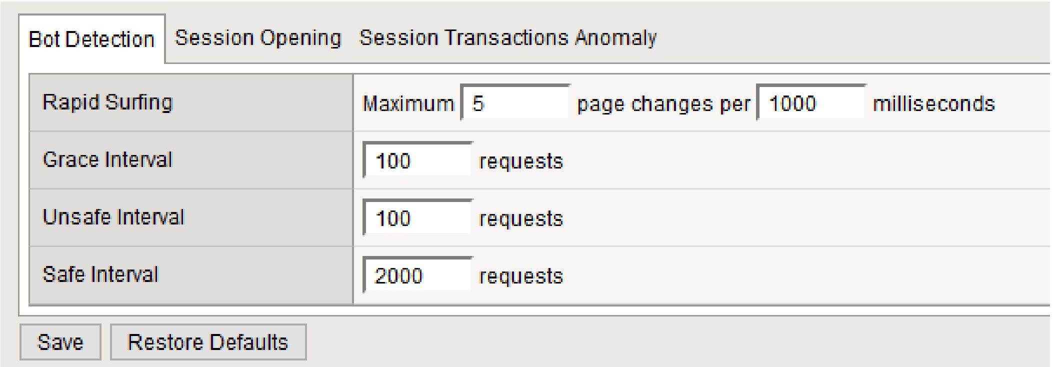


Figure 16. Bot Detection settings.

The implementation of web scraping based on session opening was next. The session opening anomaly detection will detect sessions or IP addresses that open too many sessions. Attacks can also be detected when inconsistencies and session resets reach a configured threshold. (F5 2014b.) More settings appeared on the Session Opening tab at the bottom of the screen. Session Opening Anomaly box was checked. From the prevention policy setting below *Client Side Integrity Defence* and *Rate Limiting* were enabled. Drop IP Addresses with bad reputation could not be enabled, because the IP Address intelligence module was not licensed. The Session detection criteria were left to default, as shown in figure 17.

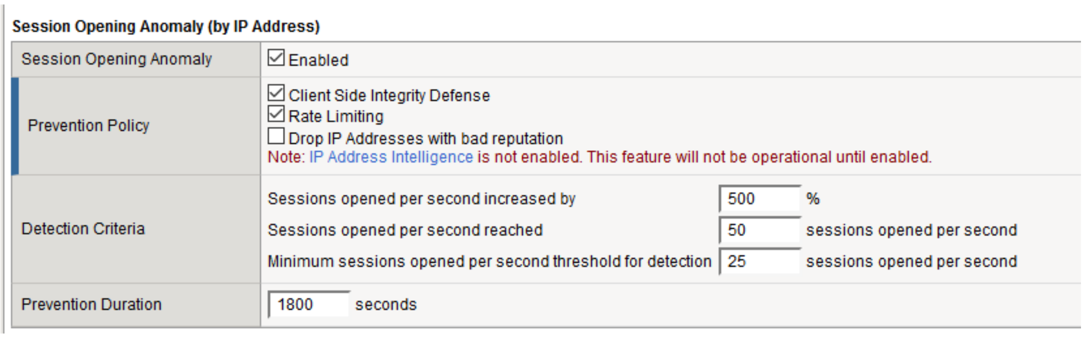


Figure 17. Session Opening Anomaly settings.

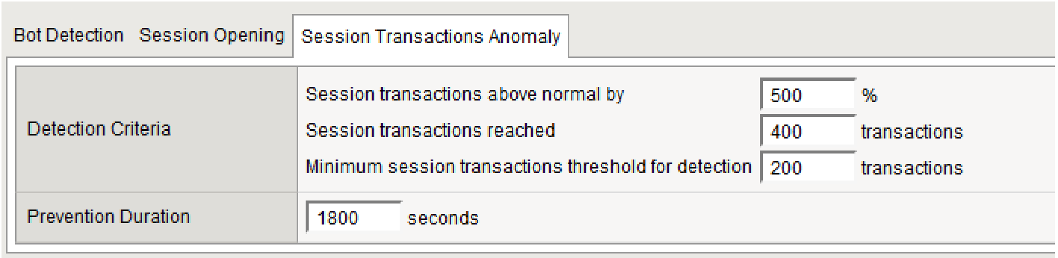
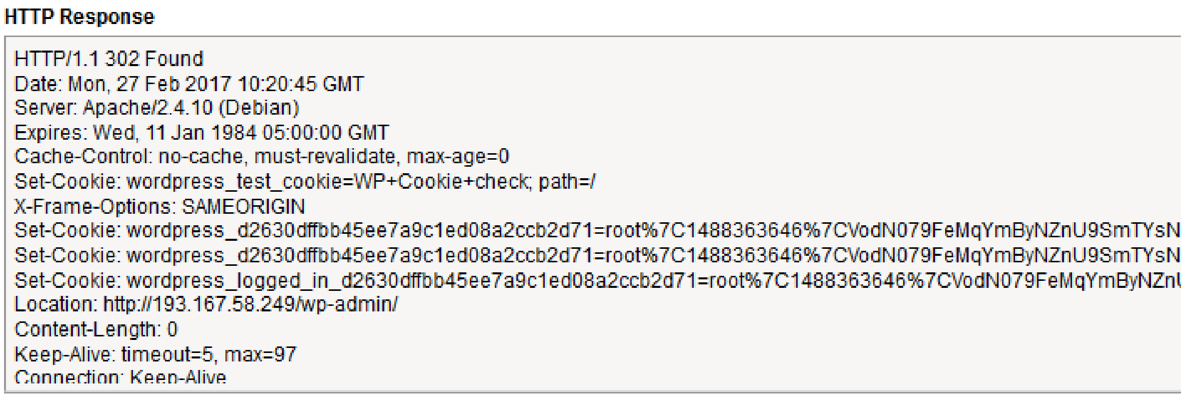


Figure 18. Session Transaction Anomaly settings.

The last option from the top *Session Transaction Anomaly* looks for sessions that request too much traffic compared to the average amount of the application. The traffic is based on TPS. (F5 2014b.) The session transaction anomaly settings are shown in figure 18. After the settings were set, the save and apply policy buttons were clicked. The default criteria were left in the settings. The detection criteria could be tuned later to decrease the chance of false bot detections or to increase the chance of detecting bots. The web scraping event logs could be seen by navigating to *Security* > *Event Logs* > *Application* > *Web Scraping Statistics.* The system should now alarm in case it detects bot activity that have not been whitelisted in the site. The web scraping option could not be tested as the CyberLab was not connected to the public Internet. In theory, the web scraping should work, but the percent and transaction options should be tuned, as in other anomaly based detection methods.

6.3.4 Brute force

The brute force attacks could also be blocked and detected on the ADC instead of using some software blockers. To use the ASM brute force blocking feature, a setup of a login page was required to be added to the ADC. Login page could be set to the ADC by going to *Security > Application Security > Login Pages* and clicking create new. To set the login page the URL of the login page, the authentication method and some parameters needed to be known. At least one access validation method was also mandatory. The authentication type in the case of the WordPress test site was “HTML Form” and the username and the password parameters, which could be found from the site source-code were “log” for the username and “pwd” for the password. To find some validation settings from the responses “Response Logging” had to be activated. After it was activated a regular login and a failed login were sent to the site. If the application security policy and the login page were set correctly the requests should appear into the log of the application security policy. When the response logging was enabled, the HTTP response could be viewed and some access validation settings were deducted from the responses as seen in figure 19, which shows a response of a successful login.


HTTP Response

```
HTTP/1.1 302 Found
Date: Mon, 27 Feb 2017 10:20:45 GMT
Server: Apache/2.4.10 (Debian)
Expires: Wed, 11 Jan 1984 05:00:00 GMT
Cache-Control: no-cache, must-revalidate, max-age=0
Set-Cookie: wordpress_test_cookie=WP+Cookie+check; path=/
X-Frame-Options: SAMEORIGIN
Set-Cookie: wordpress_d2630dffbb45ee7a9c1ed08a2ccb2d71=root%7C1488363646%7CVodN079FeMqYmByNZnU9SmTYsN
Set-Cookie: wordpress_d2630dffbb45ee7a9c1ed08a2ccb2d71=root%7C1488363646%7CVodN079FeMqYmByNZnU9SmTYsN
Set-Cookie: wordpress_logged_in_d2630dffbb45ee7a9c1ed08a2ccb2d71=root%7C1488363646%7CVodN079FeMqYmByNZn
Location: http://193.167.58.249/wp-admin/
Content-Length: 0
Keep-Alive: timeout=5, max=97
Connection: Keep-Alive
```

Figure 19. HTTP Response shown by ASM.

The successful login returned a 302 response and added a “wordpress_logged_in” cookie, which were both added to the login page settings. From the failed login the response “ERROR” could also be seen. This was added to the string that should not appear section as shown in. After the login page was completed, the brute force detection could be set up. The brute force anomaly detection setting could be found from *Security > Application Security > Brute Force Attack Prevention.* The login page created earlier was selected as the login page. The login attempt parameters on both session-based and dynamic brute force protection were set to lower to test the protection and block durations were also decreased. The complete settings can be observed in figure 20.

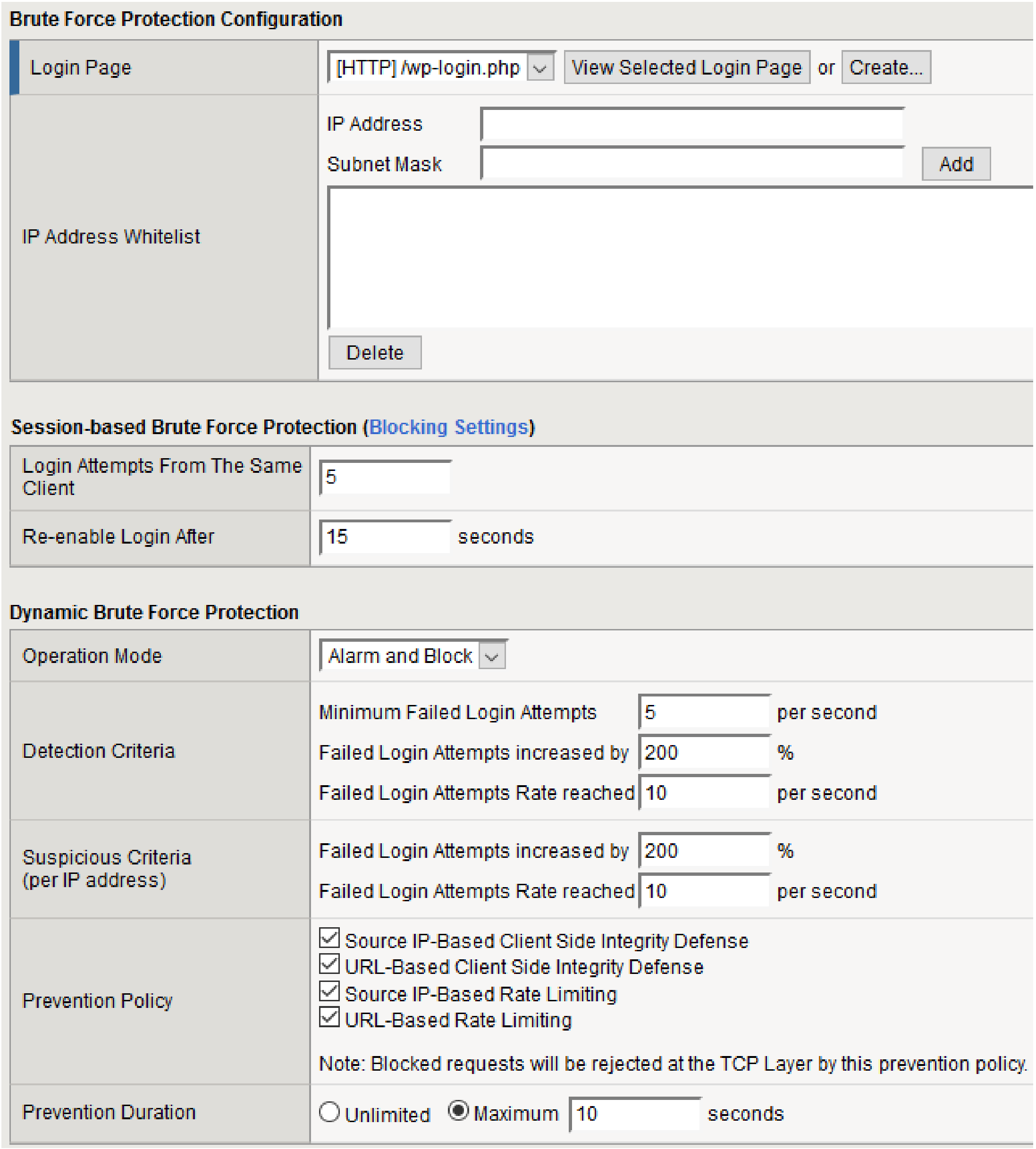


Figure 20. Brute Force Block settings.

To test whether the brute force block was working or not, a brute forcing tool was needed. A tool called WPScan was found in the Kali Linux, which is a tool exclusively for brute forcing into WordPress. The following command was entered to terminal.

wpscan --url 193.167.58.249 –wordlist /usr/share/john/password.lst --username root

The command would brute force the WordPress with the username “root” using a wordlist called password.lst, which is an over 3000 word wordlist, included with the Kali Linux. The command was run first without the brute force blocking on and the whole list was brute forced without a notice in under a minute. When the command was run with the blocking set on, WPScan started showing errors as soon as the ADC noticed the brute force attack. Based on the settings the attack could be discovered by the Application security policy or the Dynamic Anomaly detection method. If the attack was discovered by the security policy, the log could be found in the application security event logs as shown in figure 21.

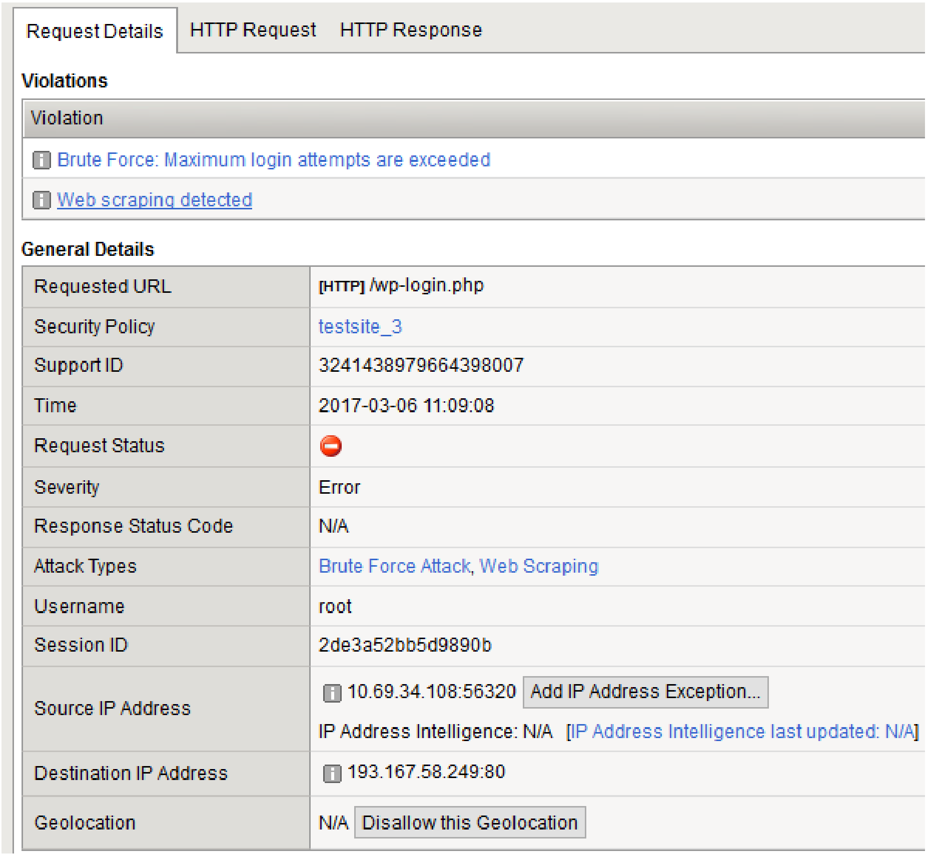


Figure 21. ASM brute force request details.

If the application security policy did not detect the brute force, the anomaly based dynamic detection would trigger if it was set on. The anomaly detection logs could be found from the *Event Logs > Application > Brute Force Attacks* and they would display more information about the attack and how it was discovered, as shown in figure 22.

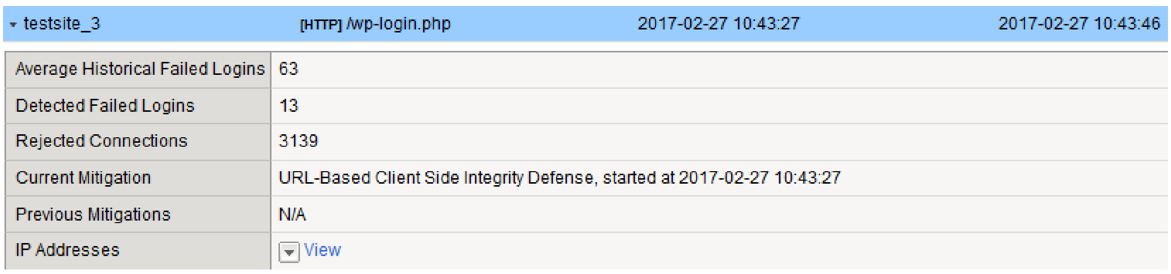


Figure 22. Brute force block logs.

6.3.5 Session tracking

With the login page created in the previous chapter, a feature called session tracking of the ASM could also be enabled. The session tracking can be used to track, enforce and report users, sessions and IP addresses. When the session tracking detects a violation, it will perform either logging or blocking actions based on a user, session and IP. The session tracking could be configured by going to *Security > Application Security > Sessions and Logins > Session tracking*. From top of the menu a login page had to be selected. In this case, the WordPress login page was used. Other settings on the top of the page were left to default. At the bottom of the menu there were three tabs, from which the different session tracking variations could be configured. The different features were called block all, log all requests and delay blocking. Only the logging setting was tested as the blocking features required other configurations. The settings on the log all requests tab had to be re configured as the amount of violations by default was too high. All of the violation parameters were set to one to as seen in figure 23.

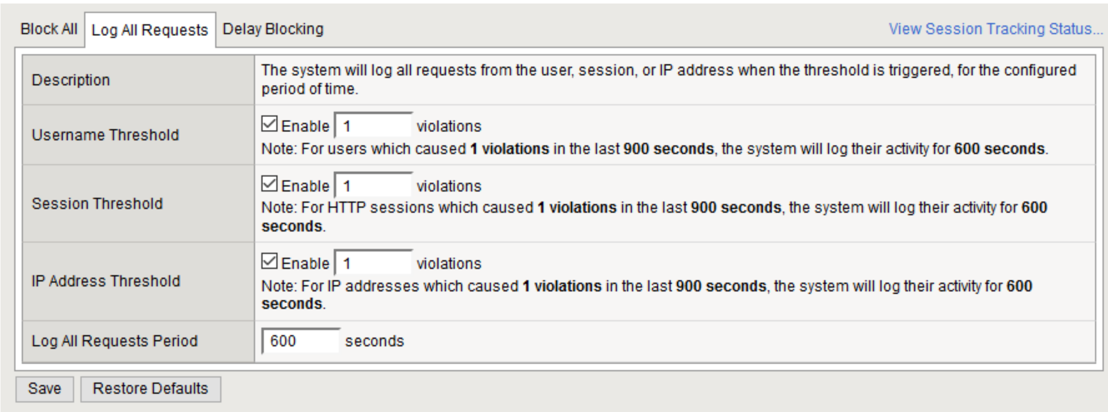


Figure 23. Session tracking log all requests.

The system should now after one violation log everything a user, session and IP-address does during 600 seconds. After the configuration two different WordPress users from different IP-addresses performed one violation determined on the application security policy on the WordPress site. The sessions should now be logged and found at *Security > Reporting > Application > Session* Tracking Status. In the logs, there were two values for usernames, sessions and IP-addresses, which confirmed the session tracking and the login page were configured correctly. The session tracking logs can be seen in figure 24. By clicking the "View Requests" button on the logs, the requests made by the client could be tracked.

Action	Scope	Value	Create Time	Expiration Time	Requests
Log All Requests	Username	root	2017-03-29 12:55:08	2017-03-29 13:05:28	View Requests
Log All Requests	Session	91276e7780ba7ab4	2017-03-29 12:55:08	2017-03-29 13:05:28	View Requests
Log All Requests	IP Address	10.69.34.112	2017-03-29 12:55:08	2017-03-29 13:05:28	View Requests
Log All Requests	IP Address	10.69.34.103	2017-03-29 12:55:36	2017-03-29 13:05:36	View Requests
Log All Requests	Username	kalle	2017-03-29 12:55:36	2017-03-29 13:05:36	View Requests
Log All Requests	Session	2e51a59d878a1b57	2017-03-29 12:55:36	2017-03-29 13:05:36	View Requests

Release

Total Entries: 6

Figure 24. Session tracking logs.

6.3.6 Mitigating specific attacks

According to Holmes most of the typical DoS attack tools in layers 2 to 7 can be blocked with the combination of ASM and AFM. However, there are some exceptions that have to be mitigated using other methods. The exceptions are SSL Renegotiation attack and Slowloris. (Holmes 2012.) The two attacks listed on the article were already tested in a related project on a virtual version of the BIG-IP so it would be interesting to see how the attacks work against the real BIG-IP devices.

As the Cybergame will be using HTTPS the SSL renegotiation attack should be mitigated. To test if the SSL renegotiation attacks were still a problem against BIG-IP and SSL, "THC SSL DOS" tool had to be used. The tool was provided by the Kali Linux and could be easily be used from the terminal. The following command was entered to the terminal of Kali:

thc-ssl-dos 193.167.58.246 443 –accept

The program only needed the IP-address and HTTPS ports of the target and asked in the end to confirm with –accept that the target was applicable to test on. When the command was entered, the handshakes went on for some time until errors started pouring in. The THC SSL tool progress can be seen in figure 25.

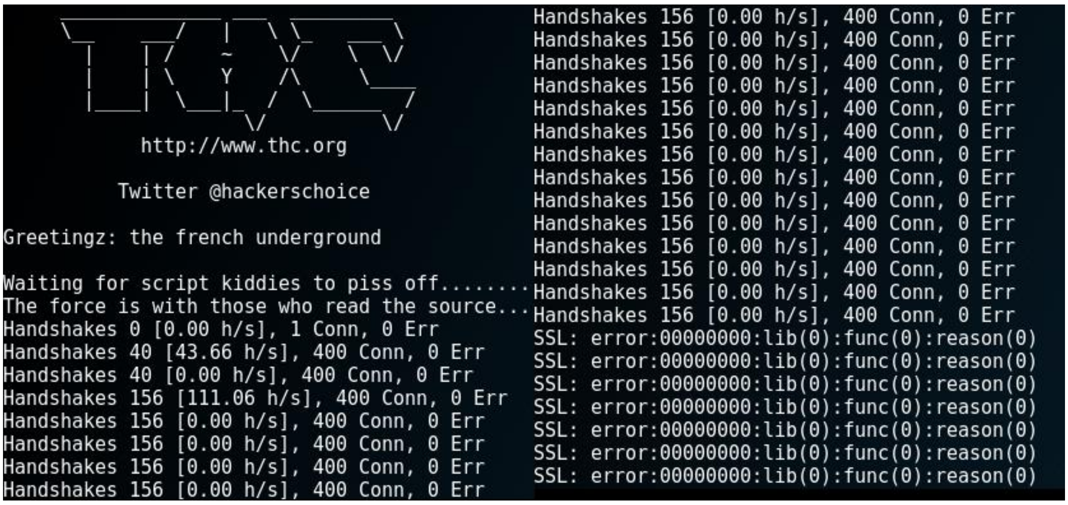


Figure 25. THC DDoS tool.

2017-03-22 06:53:44	Attack Sampled	SSL renegotiation attack	Allow	3099028406	1	0
2017-03-22 06:53:44	Attack Sampled	Flood attack	Drop	431321317	75	11
2017-03-22 06:53:44	Attack Sampled	SSL renegotiation attack	Allow	1608862782	1	0
2017-03-22 06:53:44	Attack Sampled	SSL renegotiation attack	Allow	118697158	1	0
2017-03-22 06:53:44	Attack Sampled	SSL renegotiation attack	Allow	2923498830	1	0
2017-03-22 06:53:44	Attack Sampled	SSL renegotiation attack	Allow	1433333206	1	0
2017-03-22 06:53:44	Attack Sampled	SSL renegotiation attack	Allow	4238134878	1	0
2017-03-22 06:53:44	Attack Sampled	Flood attack	Drop	431321317	142	23

Figure 26. SSL renegotiation in security logs.

After looking into the logs of the BIG-IP it was found that the something had spotted DoS automatically and rate limited the attack as shown in figure 26. According to the BIG-IP system performance logs the attack from one client only caused the system CPU usage to go up by a few percent so other mitigation methods were not necessary. Looking around the F5 site for a reason why the attack was mitigated automatically, only information about the iRule mitigation was found and nothing stating an automatic mitigation was found. After a while a F5 white paper document was found, which states that the SSL renegotiation was added to an automatic LTM SSL stack that provides the mitigation by default (F5 2014c).

To test the mitigation against Slowloris, a tool called slowhttptest was used. According to F5 the attack was mitigated automatically if an HTTP profile is used on a virtual server. The attack sends requests, which are never meant to complete to exhaust the connections of a server. If an HTTP profile is set to the BIG-IP, the attack will only consume connections on the BIG-IP instead of the application servers. When the size of the sent headers exceeds the limit set in the BIG-IP HTTP profile, the connection will reset and the device will recover TCP sockets and remove connections from the connection table, rendering the Slowloris attack useless. (F5 2017.) When the attack was tested on the testing site using slowhttptest tool the statistics page on the BIG-IP showed a small increase in processor usage and an increased amount of opened connections, but no drawbacks for the site were seen. If the attack needs to be mitigated further for some reason, the following iRule could be used:

```
when CLIENT_ACCEPTED {
setrtimer 0
after 1000 {
if { not $rtimer} {
drop
}
}
}
when HTTP_REQUEST {
setrtimer 1
}
```

(F5 2017).

6.4 Configuring optimization

Some traffic optimization features were also implemented to the ADC. The optimization features are very important to reduce the load and the traffic that goes through the ADC to the servers. If the traffic and the content were optimized, the saved resources could be for example used to mitigate DoS attacks or serve the application to the users. The optimization features were featured in the AAM module.

6.4.1 TCP multiplexing

TCP multiplexing was the first optimization setting to be implemented. TCP multiplexing feature could be found in the LTM module of the ADC by the name of OneConnect. As stated in the F5 OneConnect tuning document, the

TCP profiles of the HTTP profile that are going to be implemented with OneConnect should be changed first to the F5 default optimized profiles (F5. s.a.). First by navigating to *Local Traffic > Virtual Servers* the configured virtual server was selected.

Configuration: Advanced

Protocol	TCP
Protocol Profile (Client)	tcp-wan-optimized
Protocol Profile (Server)	tcp-lan-optimized
HTTP Profile	http

FIGURE 27. The optimized TCP profiles implemented.

Around the TCP section of the virtual server's settings, the client side TCP profile was set to *"tcp-wan-optimized"* and the server side was set to *"tcp-lan-optimized"* as shown in figure 27. Next was the implementation of OneConnect. New OneConnect profiles could be created from *Local Traffic > Profiles > Other > OneConnect*. The IP range for reused connections could be set from the OneConnect profile settings in the source mask section. OneConnect profile with a mask of 0.0.0.0 reuses all the connections and could mess up the log entries. The safest mask 255.255.255.255 was chosen, because it only reuses the same client's TCP connections. Other OneConnect settings were left to default.

Connections

Currently Idle	4
Maximum	8
Total Reuses	167
New	253

Figure 28. Oneconnect reused TCP connections.

After implementing the OneConnect profile into the virtual server, the reused TCP connections could be seen from the ADCs statistics page located at *Statistics > Module statistics > Local Traffic > Profiles summary > OneConnect.* After a couple of refreshes on the www.cybergame.fi site the statistics page showed that the TCP is multiplexed correctly as shown in figure 28.

6.4.2 HTTP compression

HTTP compression is another good way to optimize the traffic and it can be done on the ADC instead of the application servers. The profile could be created by navigating to *Local Traffic > Profiles > Services > HTTP Compression* and by clicking the create button. The content to be compressed or never compressed could be added to the content lists. To test the compression, text/, application/http, application/javascript were added to the contents list. Other settings were left to default. The content list and other settings can be seen in figure 29.

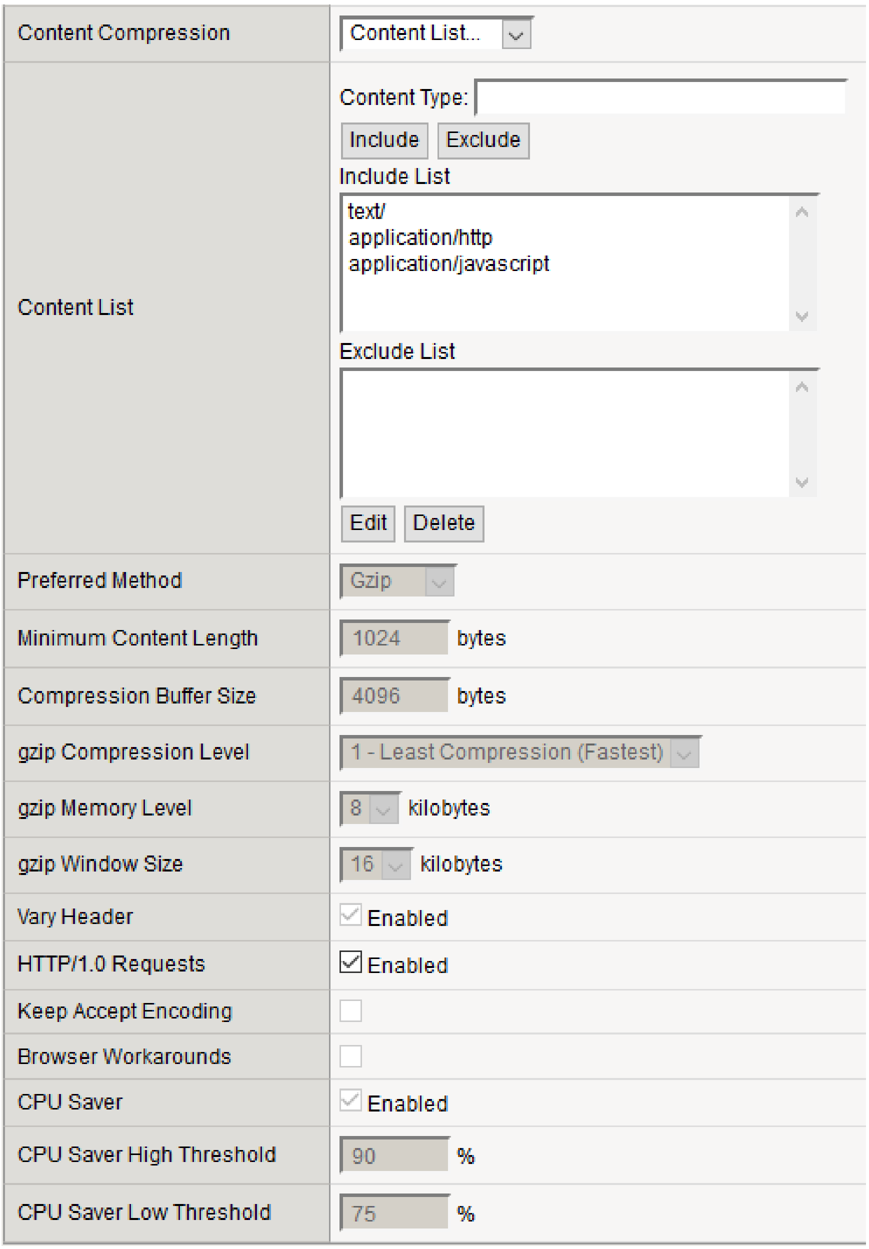


Figure 29. HTTP Compression settings.

When implementing compression into the Cybergame virtual server, the content should be changed accordingly when more about the compressible content of the Cybergame is known. The profile was then added to the virtual server of the testing application by navigating to the virtual server tab, selecting the right virtual server and scrolling to the bottom of the menu to the HTTP compression profile selection. The traffic requested from the server was now compressed. The statistics of the compression could be found in *Statistics > Module Statistics > Local Traffic > Profiles Summary > HTTP Compression,* which confirmed that the compression was working well on the test site as seen in figure 30.

Content Type Compression	Pre-Compress	Post-Compress
HTML	12.4M	5.1M
CSS	7.2M	2.3M
JS	11.3M	5.1M
XML	0	0
SGML	0	0
Plain	0	0
Image	0	0
Video	0	0
Other	59.0K	33.1K
Total	31.0M	12.8M

Figure 30. HTTP Compression statistics.

6.4.3 Web Acceleration

The last optimization feature to be implemented was the Web Acceleration, caching of static content. Combined with the HTTP compression the caching allows the ADC to cache compressed static content, improving the performance. The configuration of the Web Acceleration needs some extra tweaking to be done on the device before it can be used, if a BIG-IP ASM policy is already implemented into the device. (F5 2015). At first a new custom *Web Acceleration* profile was created, by navigating to *Local Traffic > Profiles > Services* and selecting web acceleration. For the parent profile of the new profile, “optimized-caching” was selected. Only a few settings were changed from the default. The minimum object size, which was set to 1 byte and the maximum object size which was set to 150000 bytes. The cache size was changed to 100 megabytes for this implementation. To save the profile, finish was then clicked. For the ASM and the acceleration profile to work together, a new local traffic policy had to be made. By navigating to *Local Traffic > Policies* and clicking create, a new local traffic policy was created. The new policy was named “ASM_cache_static_content”. The strategy setting selection was changed to first match. In the *Requires* setting option the *http* was moved from available to selected and from the *Controls* section both, asm and caching were moved. The changes were saved by clicking finished and the basic settings for the policy were now in place as shown in figure 31.

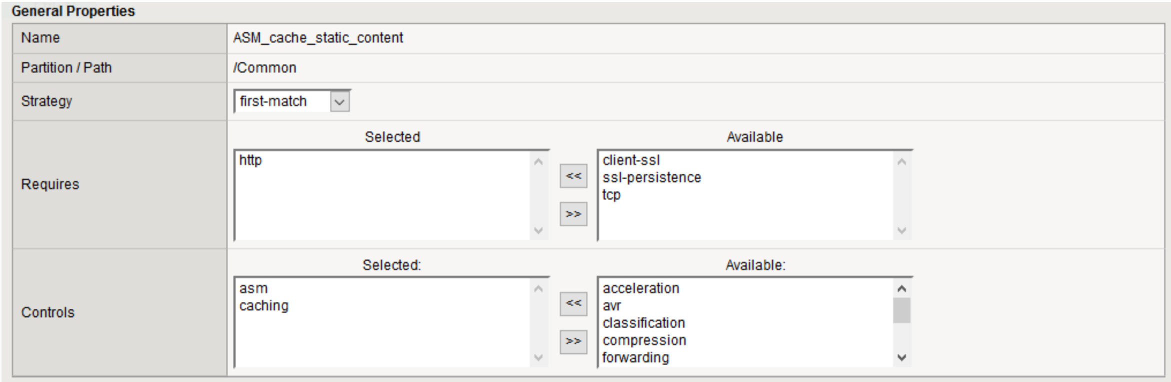


Figure 31. ASM web acceleration policy general properties.

In the *Rules* section of the panel, the add button was clicked to create rules for the policy. The first rule was named “Default_ASM_No_Cache”. In the Actions section of the rule, the following settings were added:

Target: asm
Event: request
Action: enable
Value: /Common/testsite_3

The policy will enable ASM policy called testsite_3 to the virtual server it is added. Before going any further, the policy should now be added to a virtual server. This should also be done before building a security policy with the policy builder or manually. Some recommended practices could also be done to the policy at this point, like changing the file types and URLS in the policy to wildcard and enabling blocking for certain violations. (F5 2015.) By going to *Local Traffic > Virtual Servers,* selecting the configured virtual server and clicking the resources tab the *Policies* section could be found. In the policies section Manage was clicked and the recently made “ASM_Cache_Static_Content” policy was enabled. After that the web acceleration profile that was made first, was added to the virtual server, by going to the settings of the virtual server. By navigating again to the policies section and selecting the policy that was made earlier, the policy could be reedited. The “cache_disable” rule was opened again and the following was added:

Target: cache
Event: request
Action: disable

Add was then clicked and the rule was updated. Next the rule for the caching to be was made. By clicking add button a new rule was added to the policy. The new rule was named “cache_enable”. The following *Conditions* were added to the rule:

Operand: http-uri
Event: request
Selector: extension
Condition: equals

The case sensitive box around the equals was also cleared. In the value setting next to the equals, some static content to be cached, should be added. JPG, PNG and CSS were added to the value list. The same lines to enabe the ASM policy as in the cache disable rule were added to the action section of the cache enabled rule. The actions for enabling the caching were then added to the actions section by adding the following values:

Target: cache
Event: request
Action: enable

On the policies list two rules could now be seen, like shown in figure 32. One of them disables the ASM cache and the another enables the ASM cache with the implemented file types. To determine the state of the policy the rules could be reordered in the rules menu of the policy. If the “cache_disable” rule was set on the top, the ASM cache wouldn’t be enabled. According to F5 the ASM cache should not be enabled before the application security policy building is finished and enabled on the virtual server (F5 2015). If the configuration was done correctly, the web acceleration profile should be able to serve ASM validated content from the cache, allowing ASM to focus on the dynamic content.

☑	Name	Conditions	Actions
☐	cache_disable		asm enable policy /Common/testsite_3 cache disable
☐	cache_enable	http-uri extension equals jpg png css	asm enable policy /Common/testsite_3 cache enable

Figure 32. Caching policy rules.

After the building of the application security policy was finished the cache was set to the enable state from the policy list. Some static content such as images were added to the WordPress test website. After a while, the Web Acceleration profile statistics started showing hits. The statistics for the Web Acceleration profile can be found by going to *Statistics* > *Module Statistics* > *Local Traffic* and selecting *Virtual Servers* from the drop-down menu and clicking “view…” button on the selected virtual server. From the statistics page, it could be seen that the web acceleration found content from the web page and cached the static content described in the policy created above. The statistics page can be observed in figure 33.

Profiles

Select Profile	cybergame_caching

Clear Profile Statistics

Cache

Cache Size (bytes)	448.1K
Total Cached Items	4
Total Evicted Items	0

Cache Hits / Misses	Count	Size (bytes)
Hits	19	640.2K
Misses (Cacheable)	5	458.9K
Misses (Uncacheable)	21	1.1M

Figure 33. Caching statistics.

7 CONCLUSION

The project was finished without any major failures or setbacks and can be seen as a success. With the features used in the project, the Cybergame application will have a secure and optimized framework waiting for the application to be finished. Some of the implementations created in this project can be used as they are, but it is still advised to re-configure the features when the creation of the Cybergame application is finished. The documentation included in this project should help with the process of configuring the features.

Most of the security and optimization features that could be usable in the Cybergame application were studied in this project. However, on some of the configured features only the basics things were scratched. That is mostly, because an application is required to have the configurations make any sense. For example, it is not possible to create an application security policy for an application that doesn't exist or by using another application.

As a result of the thesis work, lots of new things were learned. The knowledge of F5 ADCs went from zero to some level of expertise, because of the many hours used to configure the device and to read the F5 documentations. The configuration of the ADC features, taught a lot of new things about features that were never even heard of before this project. The importance and value of the web application security and optimization in the Cybergame and in general was noted, as they are key factors in application delivery. With some good planning and time management the progress of the work could have been smoother. The F5 documentation could have been used more from the start, since some of the implementations had to be done multiple times because of not reading the documentations well enough.

In future projects, the features studied in this work should be implemented into the Cybergame application, when the application is ready. Most of the features in this project could also be studied and implemented further when the requirements set by the Cybergame application are known. Features that include the anomaly based detection settings in the security section can be tuned better when the typical network traffic behavior is known. The optimization features could also be tuned to see on which kind of a setup they provide the most optimized traffic. The combination of application security policy and the Guacamole virtual machines needs to be researched more to implement application security into the Guacamole.

When implementing the features into the Cybergame application the most important setting, the application security policy should be done first as some of the other features require the security policy to be complete. Using the automatic policy builder, the application should be taught to the ADC by a few clients using the trusted addresses as explained in the application security chapter. When the policy is finished, it will need to be monitored for possible false entities and that it is working correctly. The violation settings of the policy, mentioned in the same chapter should also be tuned to the required settings. If the login page of the Cybergame application can be added to the ADC, as was done in the brute force chapter, the brute force protection and session tracking features can be used. The anomaly based DoS protection requires some information on the traffic of the Cybergame network, which means the application needs to be online for some time before the correct implementation is possible. The web scraping bot protection is the least important of the features but it could be worth to implement, if it is possible and protection against bots is required. The F5 websites should be studied every now and then for information and mitigation methods on new vulnerabilities. The implemented optimization features will increase the performance of the application. The TCP multiplexing and HTTP compression increase the performance even on default settings. When implementing caching with ASM set on, the application security policy should be finished and some extra configuration is also needed as done in the web acceleration chapter. All of the optimization features can be optimized when more about the application and traffic is known.

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