Impact Analysis of HTTP and SYN Flood DDoS Attacks on Apache 2 and IIS 10.0 Web Servers

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***Abstract*— Nowadays, continuously accessing Internet services is vital for the most of people. However, due to Denial of Service (DoS) and its severe type 'Distributed Denial of Service (DDoS), online services becomes unavailable to users in sometimes. Rather than DDoS is dangerous and has serious impact on the Internet consumers, there are multiple types of that attack such Slowrise, ping of death and UDP, ICMP, SYN flood, etc. In this paper, the effect of HTTP and SYN flood attack on the most recent and widely used web servers is studied and evaluated. Systematic performance analysis is performed on Internet Information Service 10.0 (IIS 10.0) on Windows server 2016 and Apache 2 on Linux Ubuntu 16.04 Long Term Support (LTS) server. Furthermore, the key metrics of the performance are average response time, average CPU usage and standard deviation as a responsiveness, efficiency and stability of the web servers. The results show that the IIS10.0 outperformed Apache2 web server in efficiency and responsiveness during HTTP flood attack. However, Apache2 web server achievement was more responsive and performed more stability with SYN flood attack.**

Keywords— DoS, DDoS, HTTP flood attack, SYN flood attack and Web server performance analysis

I. INTRODUCTION

In recent days, the majority of the Internet users are depending on web pages and web applications for transferring information and achieving most of daily routine. Moreover, all organizations and customers who rely on E-marketing, E-banking, E-learning, E-health, etc. are accomplishing their jobs through using web services [1]. This dependency on the web services increased the web servers' load radically since they are basic architectures for hosting and developing web pages and applications [2]. However, the web server who quickly responds user requests is most granular. Also quickly, continuously, and accurately accessing web service is the main demand for web developers and users [3].

On the other hand, rather than all advantages that the Internet provides for the society, there are some of the drawbacks as well, such as facing difficulties while accessing Web services. Moreover, there is no absolute safety in the public network, due to the security threats [4]. Several threats or attacks can launch through the Internet and its services become unavailable to clients. Occasionally some advanced systems become victims to attackers or hackers for example what occurred to Dyn's DNS in the late of 2016. As a result of that attack, various applications and websites were unreachable for two hours [5]. One of the threats that is used profusely by attackers with a serious and harmful effect on the network resources is DDoS [6].

DoS is considered as easy mechanism to initiate, usually implemented on a single system and difficult to defend against. The main goal of this attack is to consume the victim resources in order to deny services to normal users [7]. While DDoS attacks utilize many systems usually called Zombies and can be controlled by the attacker. A group of Zombies is used by the attacker to generate and send large number of malicious packets so that the targeted system become out of access [8]. According to worldwide infrastructure report in first quarter 2018, the DDOS attack size was as follows: 67% less than 500 Mbps, 10.8% was from 500 Mbps to 1Gbps, 8.98% was from 1Gbps to 2Gbps, 8.97 was from 2Gbps to 5Gbps and 3.02% was from 5Gbps to 10Gbps [9]. In addition, the most used ports by DDoS attack were HTTP (port 80) and HTTPS (port 443) [10]. According to a survey from 2016, the DDoS attacks can be categorized into three main types: 1) Protocol attacks; 2) bandwidth attacks; and 3) logic attacks [11]. However, according to another survey from 2013 the protocol attacks can be subdivided into two main kinds: 1) network/transport layer; and 2) application layer [12].

In this paper, the impact of the two common DDoS attacks (SYN Flood and HTTP flood) are evaluated on the two widely used web servers according to the last survey from NETCRAFT [13] on June 2018. The two depended web servers are: the last versions of IIS (i.e. IIS 10.0) on Windows server 2016, and Apache2 on Linux Ubuntu 16.04 LTS Server. The main goal of this paper is to analyze the performance of these two web servers, also to measure high availability of both web servers under two different DDoS attacks. Furthermore, the analyzing process has done in real installation network on 100 Mbps Ethernet, while the key metrics of the evaluation are response time, errors, standard deviation and CPU usage.

II. RELATED WORK

In the last three years numerous researchers evaluated and investigated the impact of several DDoS attacks types on the performance of web servers, cloud systems and big data's system. The effort of some of them is reviewed and summarized in this section.

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In [14], S. Ahmad et al evaluated and analyzed the impact of DDoS attacks on the environment that handle big data (Hadoop). They tried to determine the effect of the threats on different models and methods of the Hadoop in order to check the performance of Hadoop. Moreover, because Hadoops consist of multi-nodes, their work was implemented on a two-physical machine (single node and pseudo distributed nodes) for test and analysis. Also, they used several tools such Low Orbit Ion Canon (LOIC) and High Orbit Ion Canon (HOIC) to generate different types of attacks. The researchers analyzed the traffic load on all nodes during attacks and before attacks. They indicated that the load was from 0.1 to 0.5 Kbps without attacks but with attacks amplified to 1.6 Mbps.

In [15], D. Beckett and S. Sezer studied the flood DDoS attacks influence on the HTTP 1 and HTTP 2 in experimental work. In particular, they investigated the HTTP 2 protocol vulnerability against flood type of the DDoS attacks. Moreover, they tried to show if the risk of HTTP flood attacks is increased with launching new HTTP 2 protocol while this type of attacks was existed with HTTP 1. With the same attack resource, firstly they generated the HTTP1 attacks and then HTTP 2 attacks and sent to a web server. The results showed that the HTTP1 attacks packets were small in size and hence less consumed of the network bandwidth and had limit impact on the web server. However, the HTTP 2 attacks packets were larger and requests generation was more because each packet could handle several streams. Therefore, an attacker with last protocol version could generate more and more requests than the previous version.

In [16], M. Jiang et al proposed a method to determine the impact of application layer DDoS attacks on two different web servers (Apache and Nginx). Moreover, they generated several types of DDoS attacks against HTTP 1.1 and new version of HTTP protocol (HTTP 2.0). They evaluated the effect of attacks especially when they used dynamic and static URLs. The experimental results illustrated that there are vulnerabilities exist from both used web servers towards certain attacks. The influence of dynamic URLs application layer attacks was more for both HTTP 1.1 and HTTP 2.0. However, the server-side resources were consumed by static URLs attacks and the impact was varied on both architectures.

In [17], O. Yevsieieva and S.M. Helalat analyzed the impact of application layer DDoS attacks; in more details they studied the effect of Slow HTTP DDoS attacks on cloud environment. They evaluated the effect of the mentioned DoS and DDoS attacks on the virtual web server machine and also on the neighbor web server of the virtual machine in cloud computing. Furthermore, they used Slowrise tool to generate the attacks and the metrics researchers depended on were average CPU and RAM usage response time and also network load. The results indicated that the average memory usage raised 24.44% due to the impact of DoS attacks and 38.78% by the DDoS attacks. In addition, both attacks types (DoS and DDoS) were caused significant effect on the other performance metrics of the virtualized web servers.

In [18], A. Bhandari et al studied the effect of application layer DDoS attacks on the web server performance in the simulation environment. They used HTTP get attacks which were generated by WebTarf tool in the NS-2 simulator and they used the same tool to initiating normal HTTP requests. Moreover, they mainly depended on both average response time and throughput as a parameter to evaluate the web server performance before and during attacks. The experimental results indicated that the web server response time significantly rose when attack targeted the server; also, the throughput was badly affected by the attacks.

In [19], R. Papadie and I. Apostol studied the performance of the two widely used web servers (IIS and Apache) before and during attacks. They used two main application layer attacks which were HTTP flood and Slowrise, and they used HOIC and Slowrise tools for generating both types of the attacks. On the other side, they generated legitimated HTTP requests from virtual users by using free source Apache-Jmeter tool. In addition, the average response time was used as key of the performance of both web servers in the different environment (with and without attacks). The results illustrated that the average response time was very low of the IIS and Apache web servers before attacks, but during attacks the average response time rapidly increased to highest values.

III. HTTP FLOOD ATTACK VS SYN FLOOD ATTACK

HTTP flood attacks strategy is to exhausts the resources of the victim server by sending massive malicious requests packets such as HTP-GET and HTTP-POST requests. The target machine cannot distinguish between malicious and normal requests packets because the malicious packets have legitimated HTTP payload and the victim serve all normal and abnormal requests as a legal requests [20]. Moreover, an attacker frequently uses several infected devices with malware software known as a “bots” in order to amplify the efficiency of attack [21]. In addition, HTTP flood attacks are harder to detect since their behavior is similar to legal users, the true TCP connection is initiating between clients and server, the low traffic compared to that of TCP SYN flood attacks [20, 22].

On the other hand, the policy of TCP SYN flood attack is to consume the victim server resources or to overloads the network bandwidth by sending huge amount of data or a large number of SYN requests packets [18]. Due to large amount of data in the network or overwhelmed resources of the victim because of uncompleted mechanism of three-way handshake, the legitimated users are suffering from accessing the target server. The TCP SYN flood attack remains common attack that occurred frequently, 75% of the used attacks in the late of 2016 was TCP SYN flood [23]. The detection and mitigation process of the TCP SYN flood is not much difficult compared to the HTTP flood attack [22].

IV. EXPERIMENTAL SETUP

The study network was implemented and configured in a real network, in order to measure the performance of web servers in different cases and also to get more accurate and correct results. System and specification of the used computers in test network is illustrated in Table1.

TABLE 1. COMPUTER SPECEFICATION

Type	System	CPU	RAM	NIC
Web Servers	Dell OptiPlex 3010	Intel Core I3, 3.3 GHZ	4 GB	1000 Mbps
Clients	HP Pro Desk 400	Intel Core I7, 3.4 GHZ	4 GB	1000 Mbps
Attackers	Dell OptiPlex 3010	Intel Core I3, 3.3 GHZ	4 GB	1000 Mbps

The test network of the study was configured by 100 Mbps Ethernet, 24 ports switch. Also, computer workstations were directly connected to the switch through UTP category 6 (CAT 6) cable. The network of test is illustrated in Fig.1.

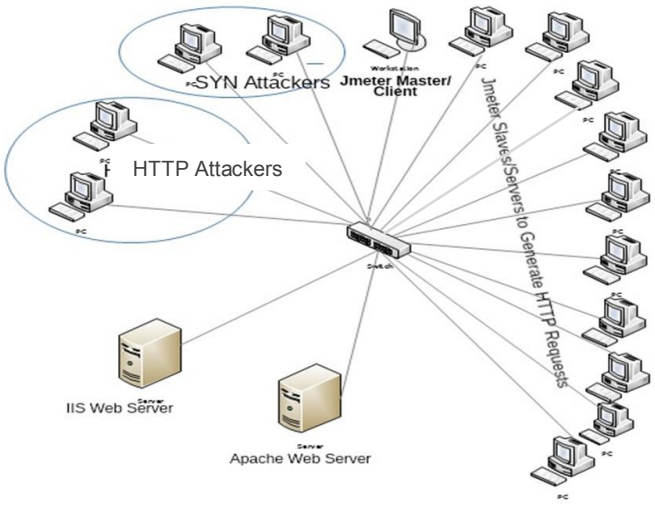

Fig. 1. Test Network

The test network was consist of 17 workstations and categorized into four types: 4 workstations used to generate (HHTP and SYN) attacks, two hosts configured as a web servers (Apache2 and IIS10.0), ten computers to generate legitimated HTTP requests, and the remained one as test controller and results collector

Apache-Jmeter 3.3 tool [24], which is pure java software, was used as normal load traffic generator. Moreover, for creating massive HTTP traffic load, distribute (remote) or client/server Jmeter testing used. The construction of the distribute testing was involved of one master 'GUI' Jmeter and tenth slaves 'command-line' Jmeter. The master Jmeter role was to create the test by generating virtual users and directing to web server in order access the home page of website. Also, its role was to collect the test results from servers (slaves Jmeter) through summary report which existed from the 'Listener' component of the test plan.

Hping3 [25] used which is command-line, built-in, and open source tool existed in Ubuntu Backtrack R5 as attacker generator. It has capability to generate several attacks types such as TCP and UDP. TCP SYN attack was created on two workstations and flood type was chosen in order to send various malicious requests packets as fast as possible to the victims.

High Orbit Cannon (HOIC) [26] used, that is an open source tool and has simple and cool GUI interface. Also, this tool has ability to send high frequency HTTP requests to the victim and targeting numerous systems simultaneously. HOIC was invoked in two hosts and utilized with scripts files to generate HTTP flood attacks.

System Activity Report (SAR) [27] is part of the sysstat package in Linux environment and has ability to report, gather and save system activity information. Due to its capability of taking snapshot of the system in determined periods, it used to monitor performance such as CPU usage, RAM utilization and Input/output (I/O) activity. SAR used to measure average CPU usage of the Ubuntu 16.04 LTS server which handle Apache2 web server.

Get-Counter [28] is a Windows PowerShell environment command that get real, live, real time data counter performance directly from Windows platform operating system. It used in Windows server 2016 in order to measure the average CPU utilization.

V. RESULTS AND PERFORMANCE ANALYSIS

In order to analyze the performance of Apache2 and IIS10.0 under high concurrent workload, five tests (5000, 10000, 15000, 20000 and 25000) of HTTP requests were performed and targeted to both of them. Furthermore, to evaluate the SYN flood and HTTP flood DDoS attacks impact on the web servers separately, numerous malicious TCP packets and high rate HTTP request were generated and directed with legitimated traffic to the victims. Moreover, to get high accuracy performance, each test was repeated more than 5 times and the period time was 120 seconds for each of the test with and without attacks. In addition, the key metrics of the evaluation process were average response time, average CPU usage, error rates and standard deviation.

A. Performance Analysis of Apache2 Web Server without Attack and With SYN and HTTP Flood DDoS Attacks

The average response time of Apache2 web servers in several legitimated HTTP request and with both SYN and HTTP flood DDoS attacks is illustrated in Fig. 2. The average response time without attack and with SYN flood attack was similar almost in all tests. Where it was 5 and 6 millisecond (ms) in the first and second tests, and remained 6 in the third test, then increased to 25 and 25 in the last test in both cases without and with SYN flood attack. However, with HTTP flood attack was 4527 ms in the first and gradually increased to reach peak 22763 ms in the last test.

Fig. 3 shows the average CPU utilization on the Apache2 web server from the first to the latest tests with both attacks. It is clearly seen that the average CPU usage of the server was (4.5%, 4.6%, 5.9%, 6.9%, and 7.9%) from the first to the last tests without attack. But with HTTP it was doubled to (8.7%, 8.9%, 8.9%, 9.5% and 9.2%) also from the first to the last tests. Moreover, the used CPU with SYN flood attack was like the first case without attack.

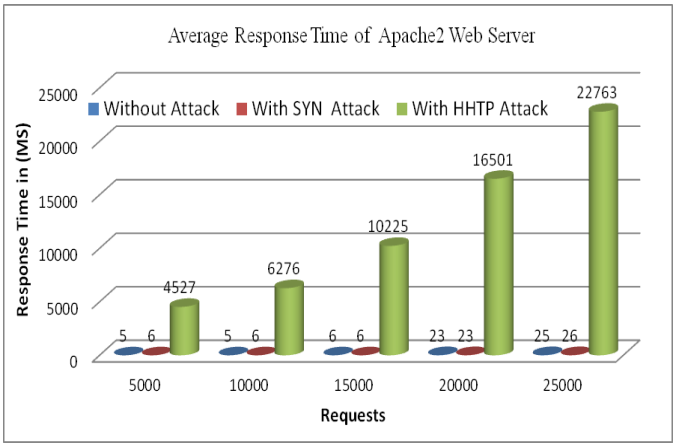

Fig. 2. Average response of Apache2 without attack and with SYN and HTTP Flood Attacks

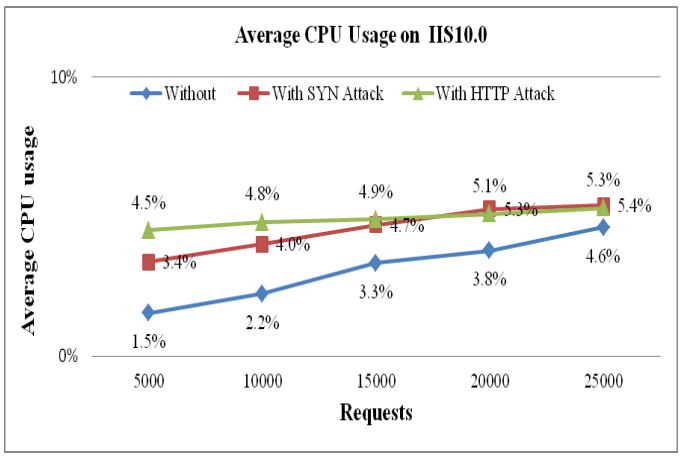

Fig. 3. Average CPU Usage on Apache2 without Attack and with SYN and HTTP flood attacks

Standard deviation which represents the dataset variability and also referred to the HTTP requests response time deviated from the average value. To achieve better and steady performances, the standard deviation value should be low [29]. Fig. 4 illustrates the standard deviation of Apache2 web server in different cases. The result indicates that there were the same values of standard deviation of the Apache2 without attacks and also with SYN attacks in all tests. Nevertheless, the worst values were achieved by the Apache2 web server was with HTTP flood attack, it was 5499.1 in the first test and dramatically increased to 36335.77 in the last test.

The error rates (failed HTTP requests) of the web server are showed in Fig. 5. The error rates without attacks and with SYN were zero percentages in all tests, but with HTTP flood attacks was 0.04% in the first test while in the rest tests increased to 0.19%, 1.35%, 3.73% and 7.63% respectively

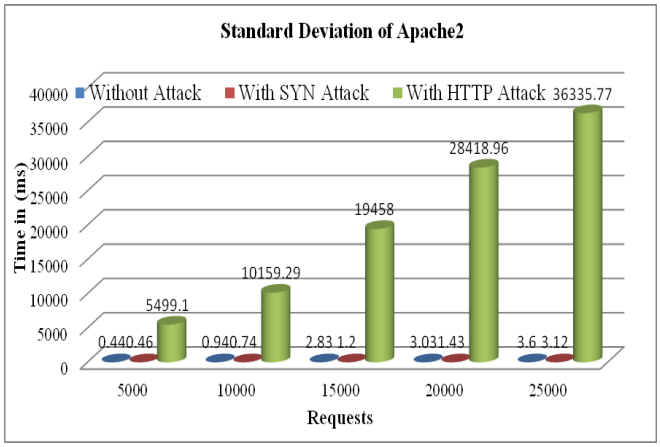

Fig. 4. Standard Deviation of Apache2 without and with SYN and HTTP Flood Attacks

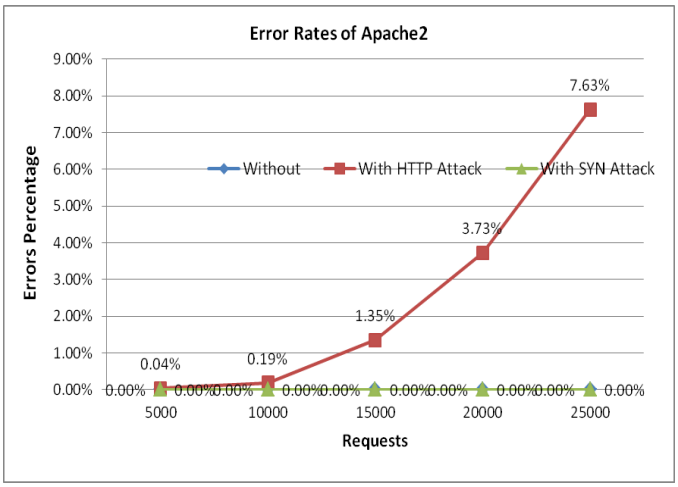

Fig.5. Error Rates of Apache2 without and with SYN and HTTP Flood Attacks

B. *Performance Analysis of IIS10.0 Web Server without Attack and With SYN and HTTP Flood DDoS Attacks*

Fig. 6 illustrates the average response time of the IIS10.0 web server through several ranges of legitimated traffic load and also with SYN and HTTP flood attacks. The average response time without attacks of the web server was 6 ms in the first and second tests subsequently then increased to 8 ms in the third test and to 25 and 27 ms in the last two tests. While with SYN flood attack fluctuated between 22 and 29 ms from the first test to the last test. Also with HTTP flood attack was 58 and 106 ms in the two first tests then amplified to 5643, 7420 and 15352 in the last three tests.

The average CPU usage on IIS10.0 through the first test to the last tests and with both attacks is showed in Fig. 7. The IIS10.0 average CPU utilization was slowly increased from 1.5% in the first to 2.2%, 3.3%, 3.8% and 4.6% in the four tests in case without attacks. However, with SYN flood attack

it was 3.4% in the first test and linearly increased to 5.4% in the last test, but with HTTP flood attack it was steady increased from 4.5 in the first test to 5.3% in the last test.

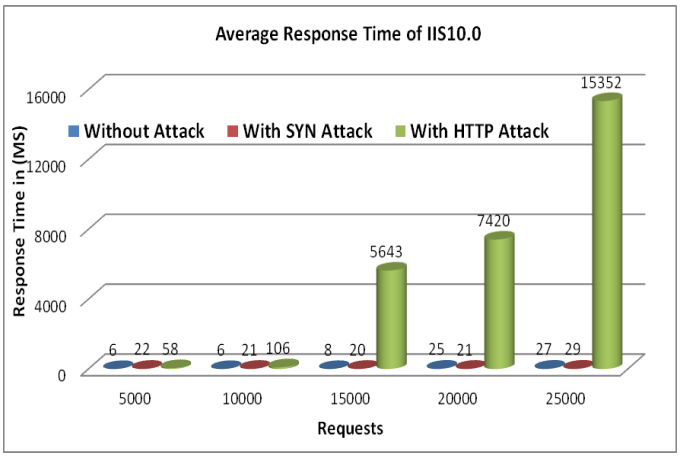

Fig. 6. Average Response Time of IIS10.0 without and with HTTP and SYN Flood Attacks

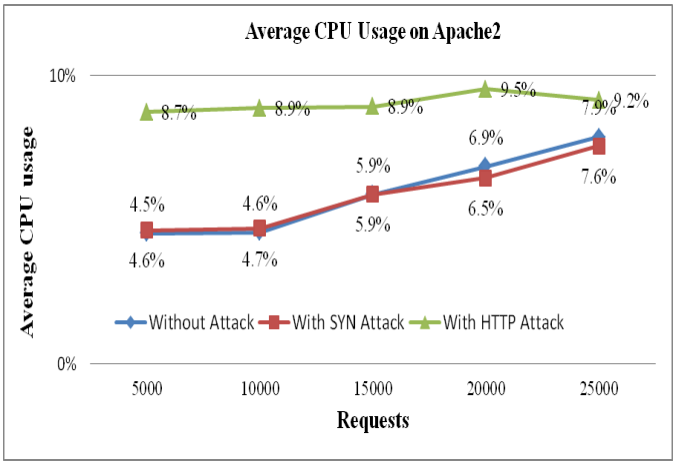

Fig. 7. Average CPU Usage on the Apache2 and IIS10.0 during HTTP Flood Attack

The standard deviation of the web servers during HTTP flood attack and legitimated HTTP requests and also with SYN flood attack is revealed in Fig. 8. The standard deviation values were very low without attacks, where it was 0.47, 1.48 and 1.71 in the first three tests, while in the last two increased to 3 and 5.36. Also, with SYN flood attack the values were 2.17, 2.85 and 2.89 in three first tests, and 2.95 and 5.1 in the last two tests. However, during HTTP flood attack the values were 56.06 and 66 in the first and second test respectively and radically increased to 3290.94, in the third test then reached to 4849.62 in the fourth test and dropped to 4449.54 in the last test

Finally, the error rates (failed HTTP requests) of IIS10.0 web servers in the first test to the last test of legitimated requests were zero percentages. Also, was 0% during HTTP and SYN flood DDoS attacks.

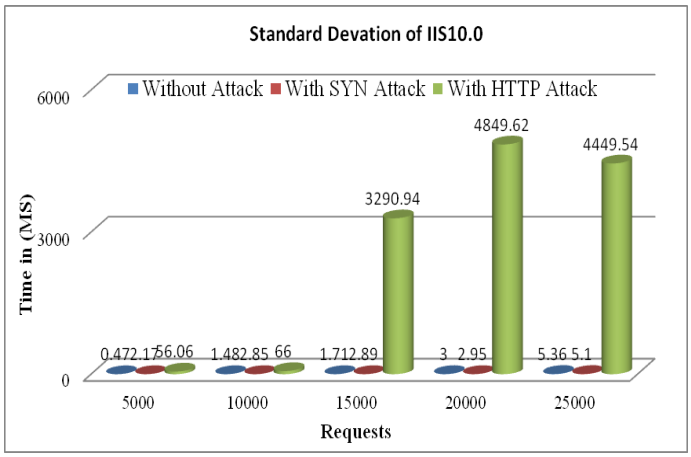

Fig. 8. Standard Deviation of IIS10.0 without and with SYN and HTTP Flood Attack

VI. CONCLUSION

The performance analysis of Apache2 on Ubuntu 160.4 LTS server and IIS10.0 on Windows server 2016 and is performed without and with DDoS attacks. The evaluation process is done on different ranges of HTTP requests in five tests and also with SYN and HTTP flood attacks. The web server's performance without attacks was as follows: Apache2 responded to the client's requests faster by 2 ms only. Also, the average CPU usage on Apache2 was twice than on IIS10.0 web server, therefore the second one is less CPU consumed on processing the legitimate traffic load. Moreover, the standard deviation value of IIS10.0 was fewer in all tests except the last test; hence it was more stable compared to Apache2 web server.

Secondly, the impact of HTTP flood DDoS attack on the web servers is evaluated. The IIS10.0 web server was more responsiveness with HTTP flood attack. Also, the average CPU utilization on Apache2 was doubled consumed compared to IIS10.0 web server from the first test to the last test. Furthermore, the first web server achieved more stable performance. Due to HTTP flood attack impact there was error rates of the responded HTTP requests from apache2 web server, where the percentage reached to 7.63% in the last test.

Thirdly, the performance of the web servers is analyzed with SYN flood attack. The average response time of the Apache2 web server was not affected by attack, while the IIS10.0 average response time fluctuated from the first test to the last. Also, the average CPU usage on the second web server was more affected to the SYN flood attack. In addition, the standard deviation value of the IIS10.0 web server was more than the Apache2 web server.

Overall, the IIS10.0 web server was more stable, efficiency and also much responsiveness during HTTP flood attack. Nevertheless, the Apache2 accomplished better performance with SYN flood attack and it was more responsive without attacks.

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