



Article

# Network Security against DDoS attacks using the Floodlight controller

## Seguridad en la Red contra ataques DDoS utilizando el controlador Floodlight

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**Abstract:** Nowadays, the Internet has become one of the most widely used platforms for conducting transactions and managing information worldwide, which highlights the need to strengthen cybersecurity systems against increasing digital threats. Among the most common attacks are Distributed Denial of Service (DDoS) attacks, which aim to disrupt the operation of networks, services, or websites by overwhelming them with massive amounts of malicious traffic, exhausting their resources and preventing legitimate requests from being processed. This project aimed to analyze and implement a simulation environment to assess service vulnerability to DDoS attacks and propose early detection and mitigation strategies. A network architecture based on Software Defined Networking (SDN) was designed using the Floodlight controller, enabling dynamic traffic management and anomaly detection. Controlled attack simulations were conducted to observe system behavior and evaluate its response capacity. The results demonstrated that integrating the Floodlight controller significantly improves detection and response to traffic saturation events, reducing the likelihood of critical service disruptions. In conclusion, SDN based environments represent an effective alternative to enhance cybersecurity in network infrastructures, providing a flexible framework for monitoring, prevention, and mitigation of DDoS.

**Keywords:** Cyber attack; DDoS attack; Floodlight; Simulation.

**Resumen:** En la actualidad, Internet constituye uno de los medios más utilizados para la realización de transacciones y la gestión de información a nivel mundial, lo que resalta la necesidad de fortalecer la seguridad de los sistemas informáticos ante el incremento de amenazas cibernéticas. Entre los ataques más frecuentes se encuentran las Denegaciones de Servicio Distribuidas (DDoS), cuyo propósito es interrumpir el funcionamiento de redes, servicios o sitios web mediante el envío masivo de tráfico malicioso, saturando los recursos del sistema e impidiendo la atención de solicitudes legítimas. El objetivo de este proyecto fue analizar e implementar un entorno de simulación que permitiera evaluar la vulnerabilidad de los servicios ante ataques DDoS y proponer estrategias de detección y mitigación temprana. Para ello, se diseñó una arquitectura de red basada en Software Defined Networking (SDN) empleando el controlador Floodlight, que facilita



la administración dinámica del tráfico y la identificación de patrones anómalos. Se realizaron pruebas controladas de ataques simulados para observar el comportamiento del sistema y medir su capacidad de respuesta. Los resultados evidenciaron que la integración del controlador Floodlight permite mejorar significativamente la detección y respuesta ante eventos de saturación de tráfico, reduciendo la probabilidad de interrupciones críticas. En conclusión, la utilización de entornos SDN constituye una alternativa eficaz para fortalecer la ciberseguridad en infraestructuras de red, brindando un marco adaptable para el monitoreo, la prevención y la mitigación de ataques DDoS.

**Palabras clave:** Ataque cibernético; Ataque DDoS; Floodlight; Simulación.

## 1. Introduction

In the current context, the Internet has become a key platform for transactions and service delivery at a global scale, which highlights the importance of protecting computer systems against cyber threats such as Distributed Denial of Service (DDoS) attacks. These attacks aim to saturate the resources of networks or applications through massive volumes of malicious traffic, thereby affecting the availability and performance of legitimate services [6].

Software-Defined Networking (SDN) has emerged as an effective approach to mitigate such attacks by centralizing traffic management and enabling rapid responses to anomalous behavior [2]. Controllers such as Floodlight are particularly relevant due to their ability to monitor network traffic, enforce dynamic rules, and filter malicious flows, thus enhancing overall network security. Additionally, the use of simulation tools such as Mininet is essential for testing mitigation strategies in controlled environments, allowing vulnerabilities to be identified and system behavior to be evaluated under realistic attack scenarios.

Numerous studies have addressed DDoS attack mitigation in SDN environments from different perspectives. According to [4], SDN represents a paradigm shift in communication networks by separating the control and data planes and relying on a centralized controller that enables flexible and adaptive network management. That work proposes a defense mechanism against HTTP flooding attacks based on a dual strategy combining proactive and reactive techniques, implemented in a Mininet-based simulated environment. The experimental results demonstrate that such mechanisms can provide an additional layer of security while preserving quality of service.

From a broader perspective, the use of SDN controllers has become a fundamental strategy for protection against DDoS attacks, particularly in scenarios involving Internet of Things (IoT) devices. In this context, controllers centralize network intelligence and allow precise traffic monitoring, facilitating the rapid identification of abnormal patterns associated with DDoS attacks and the application of immediate countermeasures, such as blocking suspicious IP addresses or limiting bandwidth. This approach has been shown to improve detection and response capabilities in controlled environments, thereby minimizing the impact of attacks on affected servers.

According to [8], effective mitigation of DDoS attacks requires centralized network administration and the application of real-time defense strategies. By implementing a centralized SDN controller, it becomes possible to continuously monitor traffic, detect attack patterns, and make rapid decisions to isolate malicious connections while maintaining service availability for legitimate users. Recent studies further demonstrate that SDN-based approaches optimize network resource utilization and reduce response times through the use of simulated attack scenarios in controlled environments, as achieved with tools such as NeSSi2.

Similarly, [1] propose effective DDoS mitigation solutions based on robust firewall configurations and software modules such as IPTables and MOD\_EVASIVE. When integrated into SDN control systems, these mechanisms can significantly reduce the load of malicious packets on servers by automatically blocking suspicious sources and enforcing request-limiting policies. Such strategies have been reported to reduce the impact of DDoS attacks on network infrastructure by up to 80%.

In this context, the present study focuses on the implementation of the Floodlight controller within simulated environments to strengthen detection and response strategies against DDoS attacks. Emphasis is

placed on the role of simulation platforms in evaluating and improving the defensive capabilities of network infrastructures, contributing to the development of more resilient and adaptive cybersecurity solutions.

This paper is structured as follows: Section 2 presents the main contributions of the study. Section 3 introduces the theoretical framework related to DDoS attacks and Software-Defined Networking. Section 4 describes the materials, tools, and experimental methodology employed. Section 5 reports and analyzes the results obtained from the simulated attack and mitigation scenarios. Finally, Section 6 summarizes the main findings and outlines future research directions.

## 2. Contributions

This research presents the following contributions:

- i. A Software-Defined Networking (SDN) architecture based on the Floodlight controller is designed and implemented to analyze and mitigate Distributed Denial of Service (DDoS) attacks within a controlled simulation environment.
- ii. A simulation-based experimental methodology using Mininet is established to reproduce both normal traffic conditions and DDoS attack scenarios, enabling systematic evaluation of network behavior under traffic saturation.
- iii. The effectiveness of centralized traffic monitoring and dynamic rule enforcement through the Floodlight controller is demonstrated, showing significant improvements in the detection and mitigation of anomalous traffic patterns associated with DDoS attacks.
- iv. Experimental results provide evidence that SDN-based solutions enhance network resilience and service availability by reducing resource exhaustion and packet loss during attack conditions.

## 3. Related Works

### 3.1. Definition and Types of DDoS Attacks

According to [9], Distributed Denial of Service (DDoS) attacks have the main objective of interrupting the normal operation of a system, network, or service by overloading its resources with an excessive volume of traffic. These attacks are classified into three main categories: volumetric, which generate a large volume of data to overload the system; protocol-based, which exploit weaknesses in network protocols to exhaust resources; and application-layer attacks, which directly affect applications or services such as web servers through disguised malicious requests. Each of these types uses different methods and metrics to measure its impact, such as bits per second (bps) or requests per second (rps).

### 3.2. Impact on Networks and Systems

DDoS attacks can cause significant consequences, such as the interruption of essential services, economic losses due to the inaccessibility of resources, and damage to the reputation of organizations. Their growth has been exponential, with an increasing number of devices connected to the network becoming targets or tools within botnets, which increases both their frequency and magnitude. Among the motivations for carrying out this type of attack are financial gain and personal interests [9].

### 3.3. Architecture and Principles of SDN

SDN separates the control plane (where network decisions are made) from the data plane (responsible for packet forwarding), centralizing network intelligence in a software controller. This facilitates the configuration and management of the network through programming, improving scalability and flexibility. The SDN architecture includes three main layers:

- Infrastructure layer: Contains devices such as switches and routers that execute the controller's instructions.
- Control layer: Where the SDN controller operates, managing forwarding decisions.
- Application layer: Integrates services and applications through specific interfaces (Northbound APIs).

This model allows networks to be configured and managed dynamically and openly, eliminating the limitations of traditional hardware-based approaches.

#### 3.4. Advantages of SDN in Network Management

According to [10], SDN provides key advantages in network management, such as centralization, which allows efficient control from a single point; flexibility to adapt the network to new services; automation, which minimizes human errors and speeds up configurations; and scalability, facilitating the incorporation of new devices through open standards such as OpenFlow. These characteristics make SDN ideal for dynamic environments such as data centers.

#### 3.5. Role of SDN Controllers in Network Security

The SDN controller is fundamental to network security, as it centralizes policy management, detects and mitigates threats, and constantly monitors the state of the network to respond to attacks in real time. In addition, it facilitates the integration of advanced security systems such as firewalls and IDS/IPS. However, as a critical point, it requires robust protection measures such as encryption, authentication, and forensic analysis to prevent vulnerabilities [10].

#### 3.6. Floodlight: Characteristics and Functionalities

Floodlight is a Software-Defined Networking (SDN) controller based on the OpenFlow protocol, developed in the Java programming language. This controller stands out for its compatibility with a wide range of devices, both physical and virtual switches, and for offering tools that facilitate the management of complex network topologies. Among its main functionalities are the creation of access control rules, remote device monitoring, and real-time visualization of the network status. In addition, Floodlight allows administrators to configure the network easily, ensuring high performance, fault tolerance, and robust security options such as user authentication, authorization, and anomaly detection [10].

#### 3.7. Security Modules in Floodlight

This controller can include several security functionalities designed to protect SDN networks. Its architecture allows the implementation of access rules through Access Control Lists (ACLs) as well as traffic segmentation policies through VLANs. It also supports advanced functions such as anomaly detection in traffic, fault recovery, and authentication and authorization tools to guarantee secure access to the controller and connected devices. These modules make Floodlight an effective solution for managing networks in a centralized manner with high levels of security [7].

#### 3.8. Floodlight Compatibility with Simulation Environments

It is widely used in simulation environments thanks to its integration with tools such as Mininet and MiniEdit, which allow the design and testing of SDN networks without the need for physical hardware. Its ability to operate on virtualized platforms such as VirtualBox, along with its support for OpenFlow, makes it ideal for educational and experimental environments. These characteristics allow users to emulate complex networks, verify host connectivity, analyze packet traffic, and optimize performance before implementing them in a physical environment [7].

#### 3.9. Mininet for the Creation of Virtual Topologies

It is a widely used network simulation tool for emulating virtual topologies (Fig 1). It allows the creation of hosts, switches, controllers, and virtual links on a physical machine, making use of optimized resources. One of its main features is the ability to design customized topologies through Python scripts or via the graphical interface Miniedit. In addition, Mininet supports OpenFlow compatible switches, making it an ideal platform for testing SDN architectures. It is a scalable, realistic, and easy-to-use solution for experimenting with complex networks without the need for physical hardware [5].

```
python Copiar código  
  
# Ejemplo básico de una red virtual en Mininet  
from mininet.net import Mininet  
net = Mininet()  
h1 = net.addHost('h1', ip='10.0.0.1')  
h2 = net.addHost('h2', ip='10.0.0.2')  
s1 = net.addSwitch('s1')  
net.addLink(h1, s1)  
net.addLink(h2, s1)  
net.start()  
net.pingAll()  
net.stop()
```

**Figure 1.** Creation of a topology.

Source: The authors.

### 3.10. Use of ICMP Tools such as Ping for Connectivity Testing

Ping is a fundamental tool that uses the Internet Control Message Protocol (ICMP) to verify connectivity between devices in a network (Fig 2). In simulations performed with Mininet, it allows verification that nodes are properly interconnected. In addition, it measures packet latency and diagnoses issues such as data loss or high response time. This simple yet powerful command is essential for validating configurations in virtual networks and ensuring their operability [5].

```
bash Copiar código  
  
mininet> h1 ping h2
```

**Figure 2.** Verification of connectivity between h1 and h2.

Source: The authors.

### 3.11. Simulation of Traffic and Attacks in Controlled Environments

Mininet allows the emulation of network traffic and attack scenarios in a safe and controlled environment, facilitating the evaluation of security configurations and network performance. For example, it is possible to generate traffic between nodes using tools such as iperf to measure bandwidth or to simulate DoS attacks to analyze network resilience (Fig 3). These simulations are useful for testing security policies, such as Access Control Lists (ACL) and firewall configurations, before their implementation in real networks [5].

```
bash Copiar código  
  
mininet> iperf h1 h2
```

**Figure 3.** Simulation of traffic and attacks.

Source: The authors.

### 3.12. Monitoring and Analysis of Anomalous Traffic

Monitoring and analyzing anomalous traffic is based on the constant observation of the network to identify unusual behavior patterns that may indicate a DDoS attack. This strategy uses advanced tools such as Intrusion Detection Systems (IDS) and packet analysis to identify abnormal data flows. For example, sudden spikes in traffic volume, suspicious IP addresses, or repeated attempts to access restricted resources

are monitored. These indicators allow for the implementation of rapid responses to mitigate the impact, such as temporarily blocking suspicious addresses or limiting bandwidth [3].

### 3.13. Filtering of Malicious Packets

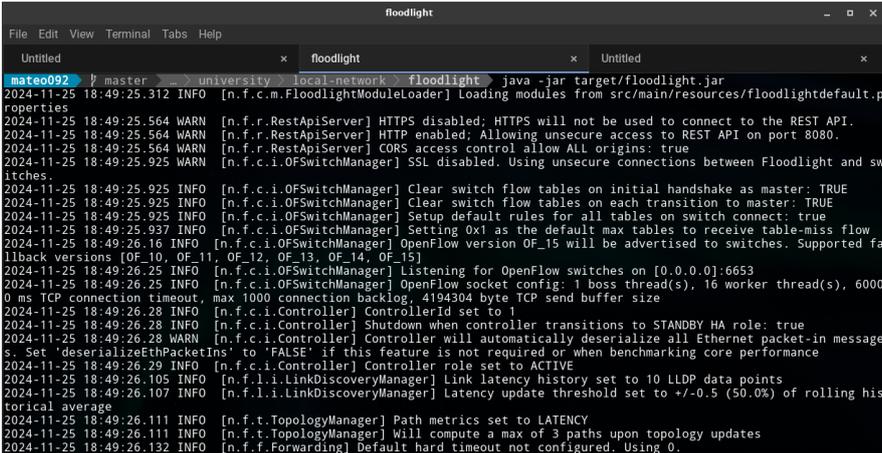
This is a mitigation technique that involves inspecting incoming data packets to detect harmful content. Through the use of firewalls, Access Control Lists (ACL), and Deep Packet Inspection (DPI) technologies, suspicious or malicious requests are discarded before they reach the servers. This process includes identifying attack signatures, malicious IP addresses, and traffic patterns that match known attacks, ensuring that only legitimate packets gain access to network resources [3].

## 4. Materials and Methods

### 4.1. Preparation of the Test Environment

To carry out the DDoS attack mitigation experiment, a controlled environment was created to replicate the behavior of a real network. This process involved the use of specific tools such as Mininet for network simulation, Floodlight as the SDN controller, and a custom script designed to monitor and analyze network traffic.

First, the Floodlight controller (Fig. 4) was executed, which was responsible for managing the network workflows.



```

floodlight
File Edit View Terminal Tabs Help
Untitled x floodlight x Untitled
mateo092 @ master ~$ university local-network floodlight java -jar target/floodlight.jar
2024-11-25 18:49:25.312 INFO [n.f.c.m.FloodlightModuleLoader] Loading modules from src/main/resources/floodlightdefault.p
roperties
2024-11-25 18:49:25.564 WARN [n.f.r.RestApiServer] HTTPS disabled; HTTPS will not be used to connect to the REST API.
2024-11-25 18:49:25.564 WARN [n.f.r.RestApiServer] HTTP enabled; Allowing unsecure access to REST API on port 8080.
2024-11-25 18:49:25.564 WARN [n.f.r.RestApiServer] CORS access control allow ALL origins: true
2024-11-25 18:49:25.925 WARN [n.f.c.i.OFSwitchManager] SSL disabled. Using unsecure connections between Floodlight and sw
itches.
2024-11-25 18:49:25.925 INFO [n.f.c.i.OFSwitchManager] Clear switch flow tables on initial handshake as master: TRUE
2024-11-25 18:49:25.925 INFO [n.f.c.i.OFSwitchManager] Clear switch flow tables on each transition to master: TRUE
2024-11-25 18:49:25.925 INFO [n.f.c.i.OFSwitchManager] Setup default rules for all tables on switch connect: true
2024-11-25 18:49:25.937 INFO [n.f.c.i.OFSwitchManager] Setting 0x1 as the default max tables to receive table-miss flow
2024-11-25 18:49:26.16 INFO [n.f.c.i.OFSwitchManager] OpenFlow version OF_15 will be advertised to switches. Supported fa
llback versions [OF_10, OF_11, OF_12, OF_13, OF_14, OF_15]
2024-11-25 18:49:26.25 INFO [n.f.c.i.OFSwitchManager] Listening for OpenFlow switches on [0.0.0.0]:6653
2024-11-25 18:49:26.25 INFO [n.f.c.i.OFSwitchManager] OpenFlow socket config: 1 boss thread(s), 16 worker thread(s), 6000
0 ms TCP connection timeout, max 1000 connection backlog, 4194304 byte TCP send buffer size
2024-11-25 18:49:26.28 INFO [n.f.c.i.Controller] ControllerId set to 1
2024-11-25 18:49:26.28 INFO [n.f.c.i.Controller] Shutdown when controller transitions to STANDBY HA role: true
2024-11-25 18:49:26.28 WARN [n.f.c.i.Controller] Controller will automatically deserialize all Ethernet packet-in message
s. Set 'deserializeEthPacketIns' to 'FALSE' if this feature is not required or when benchmarking core performance
2024-11-25 18:49:26.29 INFO [n.f.c.i.Controller] Controller role set to ACTIVE
2024-11-25 18:49:26.105 INFO [n.f.l.i.LinkDiscoveryManager] Link latency history set to 10 LLDP data points
2024-11-25 18:49:26.107 INFO [n.f.l.i.LinkDiscoveryManager] Latency update threshold set to +/-0.5 (50.0%) of rolling his
torical average
2024-11-25 18:49:26.111 INFO [n.f.t.TopologyManager] Path metrics set to LATENCY
2024-11-25 18:49:26.111 INFO [n.f.t.TopologyManager] Will compute a max of 3 paths upon topology updates
2024-11-25 18:49:26.132 INFO [n.f.f.Forwarding] Default hard timeout not configured. Using 0.

```

**Figure 4.** Execution of the Floodlight controller.

Source: The authors.

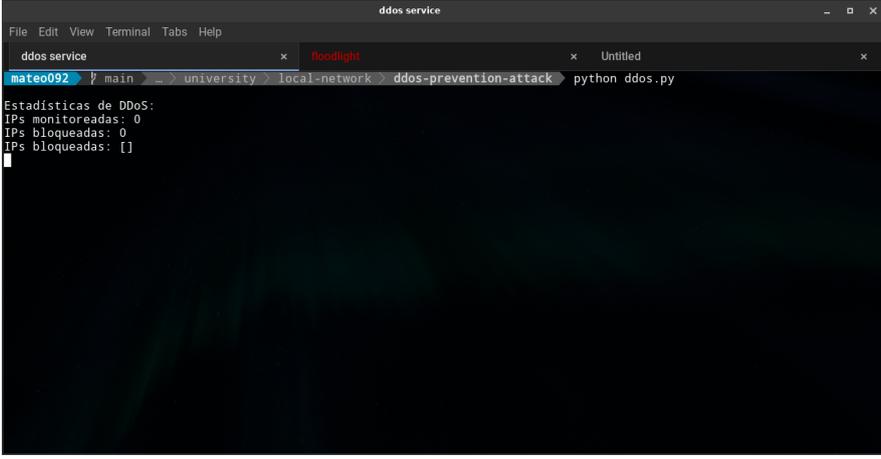
Second, the script (Fig. 5) responsible for monitoring possible DDoS attacks was run. This script records and displays detailed statistics in the console, including information about monitored hosts and those that have been blocked as part of the mitigation measures.

Subsequently, a network topology was configured, consisting of a central switch connected to seven hosts (Fig. 6), representing a typical network scenario. Figure 7 graphically illustrates this topology as visualized in the controller's web interface.

### 4.2. DDoS Attack Simulation

Once the test environment configuration was completed, the generation of normal traffic in the network began (Fig. 8), using the ping command between host1 and host3. As a result, responses were obtained from host3 along with their statistics, demonstrating that connectivity between both hosts was functioning correctly.

Finally, to simulate the DDoS attack, the ping command with the -f parameter was used between host2 and host4. In Figure 9, it can be observed that the first packets sent are correctly responded to by host4;

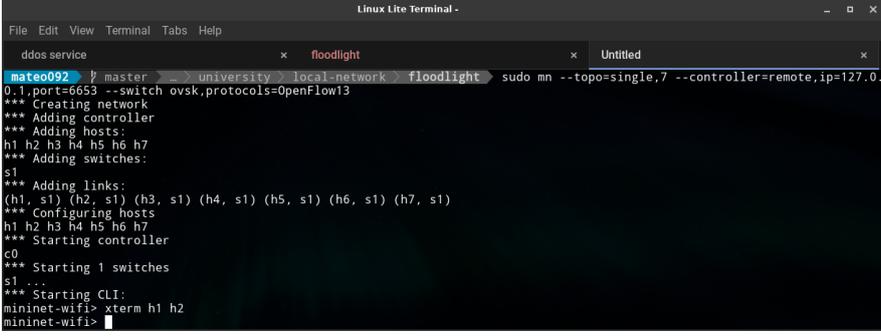


```

ddos service
File Edit View Terminal Tabs Help
ddos service x floodlight x Untitled
mateo092 ~ main ~ university ~ local-network ~ ddos-prevention-attack ~ python ddos.py
Estadísticas de DDoS:
IPs monitoreadas: 0
IPs bloqueadas: 0
IPs bloqueadas: []

```

**Figure 5.** Execution of the DDoS attack prevention script.



```

Linux Lite Terminal -
File Edit View Terminal Tabs Help
ddos service x floodlight x Untitled
mateo092 ~ master ~ university ~ local-network ~ floodlight ~ sudo mn --topo=single,7 --controller=remote,ip=127.0.
0.1,port=6653 --switch ovsk,protocols=OpenFlow13
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3 h4 h5 h6 h7
*** Adding switches:
s1
*** Adding links:
(h1, s1) (h2, s1) (h3, s1) (h4, s1) (h5, s1) (h6, s1) (h7, s1)
*** Configuring hosts
h1 h2 h3 h4 h5 h6 h7
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Starting CLI:
mininet-wifi> xterm h1 h2
mininet-wifi>

```

**Figure 6.** Execution of the topology in Mininet.

Source: The authors.

however, once the massive sending of packets begins, they are represented in the console as dots, highlighting the intensity of the generated traffic.

## 5. Results

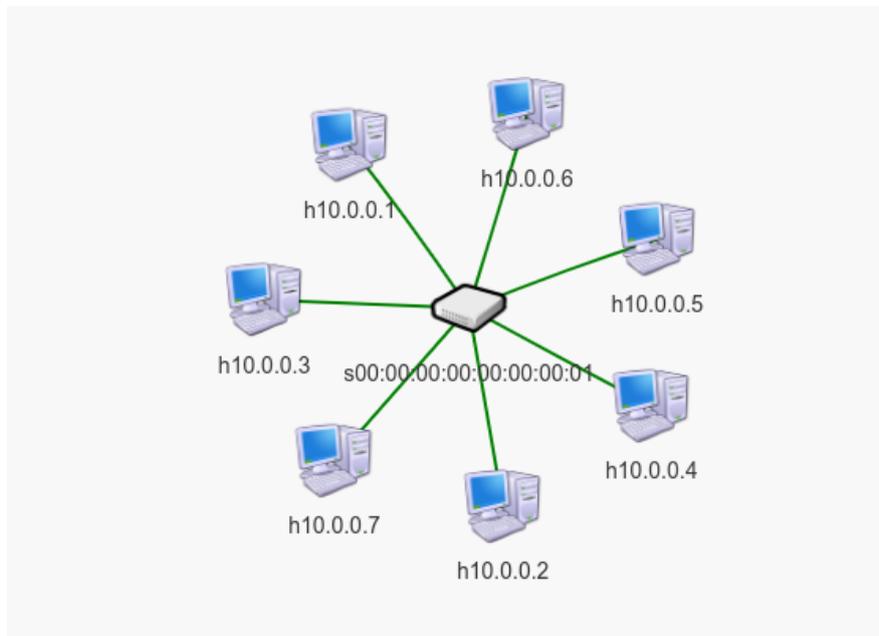
During the execution of the experimental section, a detailed monitoring of the number of packets sent over time was carried out, covering the different scenarios considered (Fig. 10). This analysis made it possible to identify traffic patterns under both normal conditions and during the simulation of a DDoS attack.

Figure 11 shows the packet traffic sent by different hosts over time. The orange line represents the traffic between hosts 10.0.0.1 and 10.0.0.3, showing a constant increase. Meanwhile, the brown line reflects the rise in packet transmission from host 10.0.0.2 to host 10.0.0.4, which initially corresponds to a normal traffic environment.

After a few seconds, host 4 begins to receive more than 50,000 packets, indicating an unusual behavior compared to the other hosts. This abrupt increase stands out in the graph, making the traffic sent to host 3 appear insignificant in relative terms (Fig. 12).

Once the script in charge of preventing DDoS attacks detects this unusual behavior, it sends the necessary rules to the controller to block the host generating the massive traffic. This prevents further resource consumption and mitigates the impact of the attack.

In the ping command statistics, out of the 104,445 packets transmitted over a 12-minute period, 42% were not received by the host. This packet loss is due both to the impact of the massive traffic and to the action of the script responsible for blocking the sending host, thus mitigating excessive resource consumption in the network.



**Figure 7.** Network topology simulated in Mininet.  
Source: The authors.

```

"Node: h1"
Welcome to Linux Lite 6.6
You are running in superuser mode, be very careful.
lunes 25 noviembre 2024, 18:25:41
Memory Usage: 3530/7837MB (45.04%)
Disk Usage: 71/117GB (64%)
root@master: ~# university local-network floodlight ping 10.0.0.3
-c 1000
PING 10.0.0.3 (10.0.0.3) 56(84) bytes of data:
64 bytes from 10.0.0.3: icmp_seq=1 ttl=64 time=114 ms
64 bytes from 10.0.0.3: icmp_seq=2 ttl=64 time=0.625 ms
64 bytes from 10.0.0.3: icmp_seq=3 ttl=64 time=0.107 ms
64 bytes from 10.0.0.3: icmp_seq=4 ttl=64 time=0.161 ms
64 bytes from 10.0.0.3: icmp_seq=5 ttl=64 time=0.134 ms
64 bytes from 10.0.0.3: icmp_seq=6 ttl=64 time=0.124 ms
64 bytes from 10.0.0.3: icmp_seq=7 ttl=64 time=0.159 ms
64 bytes from 10.0.0.3: icmp_seq=8 ttl=64 time=0.103 ms
64 bytes from 10.0.0.3: icmp_seq=9 ttl=64 time=0.148 ms
64 bytes from 10.0.0.3: icmp_seq=10 ttl=64 time=0.146 ms
64 bytes from 10.0.0.3: icmp_seq=11 ttl=64 time=0.132 ms
64 bytes from 10.0.0.3: icmp_seq=12 ttl=64 time=0.117 ms
64 bytes from 10.0.0.3: icmp_seq=13 ttl=64 time=0.171 ms
    
```

**Figure 8.** Execution of the ping command between host1 and host3.  
Source: The authors.

### 6. Conclusions

This study evaluated the effectiveness of the Floodlight controller in mitigating DDoS attacks within environments based on Software-Defined Networks (SDN). The experimental results demonstrated that the implemented architecture allows the identification and blocking of anomalous traffic patterns in real time, significantly reducing resource saturation and packet loss, which in the test scenarios reached up to 42% before system intervention.

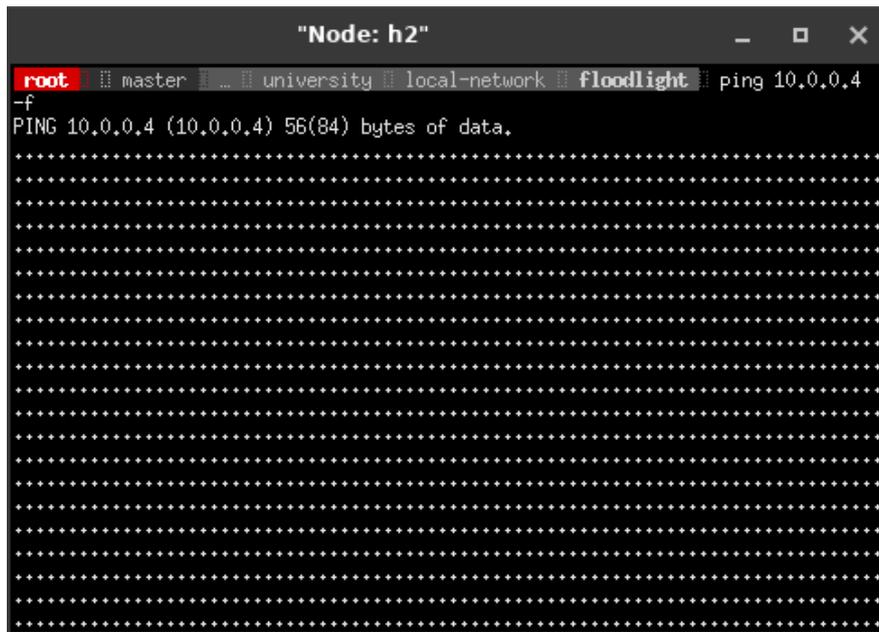


Figure 9. Execution of the ping command between host1 and host2 with the -f parameter. Source: The authors.

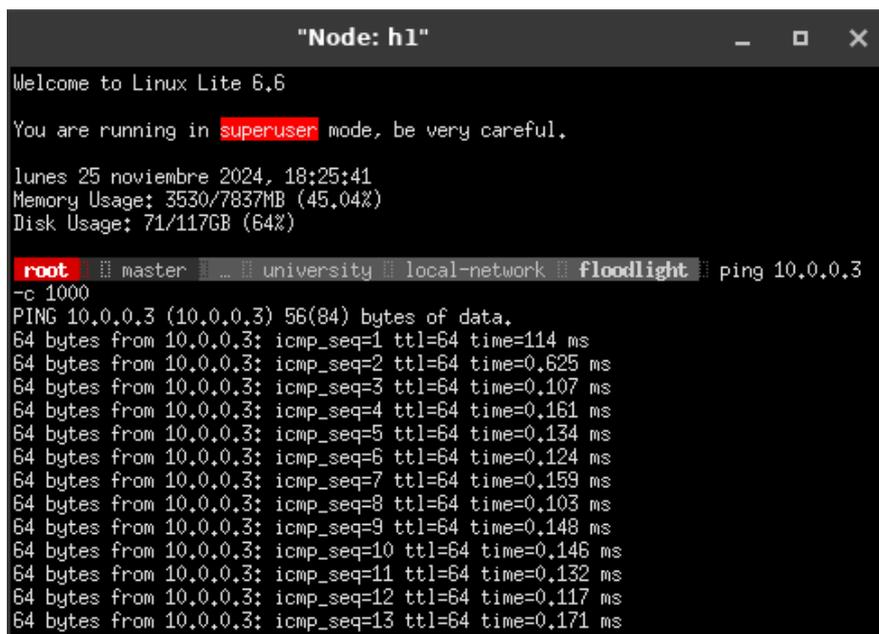
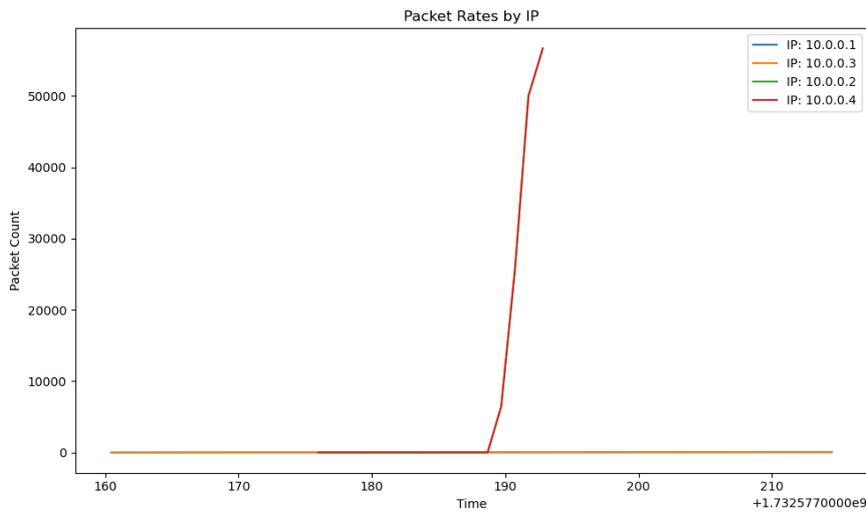


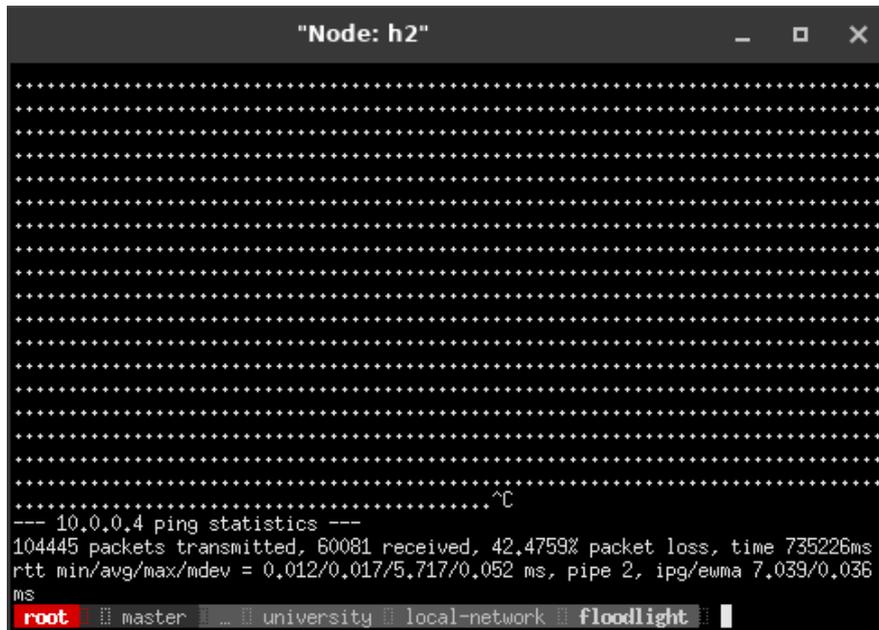
Figure 10. Normal packet traffic rate between hosts (IP: 10.0.0.1, 10.0.0.3, 10.0.0.2, and 10.0.0.4) as a function of time. Source: The authors.

The simulation in Mininet made it possible to analyze network behavior in a controlled manner under different levels of attack, showing that the automatic response of the controller prevents critical interruptions and improves service availability. This approach confirms that SDNs represent an efficient and scalable alternative to strengthen cybersecurity in network infrastructures.

Likewise, the integration of Floodlight with detection and filtering modules proved to be a viable strategy for implementing adaptive defense policies, adjustable to the dynamic conditions of traffic. It is



**Figure 11.** Exponential increase in packet traffic rate during the DDoS attack.  
Source: The authors.



**Figure 12.** Network statistics after DDoS attack mitigation.  
Source: The authors.

recommended to further explore future research lines aimed at incorporating machine learning and predictive analysis techniques to anticipate malicious behavior and optimize response times to security incidents.

Overall, the findings of this research provide practical evidence of the capability of SDN controllers to manage complex environments, offering a solid framework for the development of preventive and mitigation solutions against DDoS attacks in modern networks.

**Author Contributions:** **Eylin Ortega:** Software, Visualization, Validation, Formal analysis, Investigation, Resources. **Carlos Martínez:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Jorge Gómez:** Data curation, Supervision, Project administration, Funding acquisition.

All authors have read and agreed to the published version of the manuscript. Refer to the [taxonomía CRediT](#) for term explanations. Authorship should be limited to those who have contributed substantially to the work reported.

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**Informed Consent Statement:** This study is limited to the use of technological resources, so no human personnel or animals are involved.

**Conflicts of Interest:** Under the authorship of this research, it is declared that there is no conflict of interest with the present research.

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