**Amalgamation Ethereum Smart Contracts to Routing Information Protocol to Extenuate DDoS Attacks**

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**Abstract**

The spread of Distributed Denial of Service (DDoS) assaults, which overwhelm networks with data and cause them to malfunction normally, is a result of people's growing reliance on the internet. Researchers have looked into using blockchain-based methods to defend against these attacks. Smart contracts are provided by Ethereum, a well-known blockchain platform, and they enable the generation of self-executing contracts that can be used to manage transactions and automate corporate procedures. In order to reduce DDoS attacks, we suggest integrating Ethereum smart contracts with the Routing Information Protocol (RIP) in this study. The RIP is a commonly used internet protocol that gives routers the routing information they need to forward packets to their intended locations. We can build a decentralised, open, and DDoS-resistant network by including smart contracts into RIP. The suggested approach makes use of smart contracts to control the RIP routing tables, which list the most effective routes to a specific location. These automated smart contracts can be used to keep an eye on the network for unusual traffic patterns. Smart contracts have the ability to drop packets entirely or reroute traffic in the event of a DDoS attack, thwarting the attack. Compared to conventional DDoS mitigation strategies, our suggested method provides a number of benefits. It does this by first offering a decentralised and open network, which makes it challenging for attackers to manipulate routing tables. Second, because smart contracts are executed on a distributed network, it is immune to attacks on centralised infrastructure. Last but not least, it is simple to put into practise since Ethereum offers a user-friendly environment for developing and deploying smart contracts.

**Keywords:-** DDoS – Distributed Denial of Service, RIP – Routing Information Protocol, SDN -Software Defined Networking, SYN – Synchronized Sequence Number, WANETs -Wireless Ad Hoc Networks, V2V – Vehicle to Vehicle, PCL – Plan Check List, ICMP – Internet Control Message Protocol, NTP – Network Time Protocol

**Introduction**

A distributed denial-of-service (DDoS) attack is a malicious attempt to obstruct a server, service, or network's regular traffic by saturating the target or its surrounding infrastructure with an excessive amount of Internet traffic. By using numerous compromised computer systems as sources of attack traffic, DDoS attacks are made effective. Computers and other networked resources, like as IoT devices, can be exploited machines.

When viewed from a distance, a DDoS assault resembles an unexpected traffic congestion that blocks the roadway and keeps ordinary traffic from reaching its destination. Each bot in the botnet sends queries to the IP address of the victim's server or network when that server or network is being targeted by the botnet. This could overload the server or network and result in a denial-of-service attack on regular traffic.

An internet connection that is not protected by a firewall may be used by an IoT device. The hacker would then concentrate on this gadget and use it to launch a DDoS attack against the website of your business or another target. Your business could suffer greatly if your company's website is offline. Taking efforts to safeguard all of your devices is the best defence against IoT DDoS attacks.

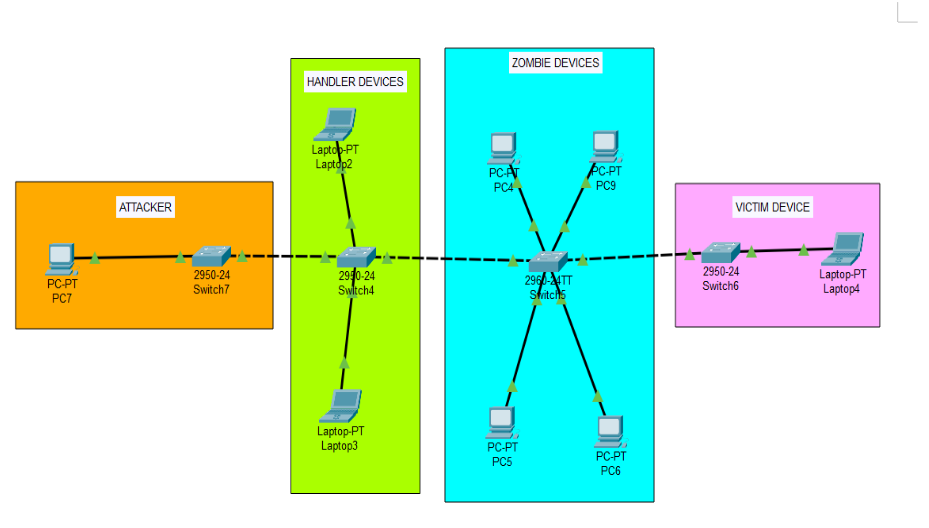


Fig 1 – Insight of a DDoS attack

Fig 1 depicts a common scenario in a DDoS attack, where a single attacker uses multiple compromised devices (known as "zombies") to overwhelm a victim's network or server with traffic. In the diagram, the attacker is shown as a single entity, which initiates the attack by sending commands to two "handlers" (sometimes called "command-and-control servers"), which in turn send instructions to four compromised devices or "zombies". These zombies then flood the victim's network or server with traffic, effectively rendering it unavailable to legitimate users. The victim, represented as a separate entity in the diagram, is depicted as being overwhelmed by the flood of traffic from the zombies. This can lead to a variety of negative outcomes, including slow or unresponsive websites, disrupted business operations, or even financial losses. DDoS attacks can be launched from anywhere in the world, making it difficult for victims to trace the source of the attack or identify the attackers. In some cases, attackers may use sophisticated techniques such as IP spoofing to further obfuscate their identities and make it more difficult for defenders to mitigate the attack.

In our project, we have used Blockchain for mitigating DDoS attack. Blockchain technology has gained significant attention in recent years, with Ethereum being one of the most popular blockchain platforms. Ethereum is a decentralized platform that allows the creation and execution of smart contracts, which are self-executing contracts with the terms of the agreement between the parties being directly written into code. Smart contracts offer a transparent and decentralized approach to automate agreements and transactions, without the need for intermediaries or trusted third parties.

The essential building blocks of Ethereum applications are smart contracts. They are computer programmes that enable turning conventional contracts into digital counterparts and are kept on the blockchain. Smart contracts have a fairly logical structure that uses an "if this, then that" formula. This means that they follow their programming exactly and cannot be influenced. By converting an agreement's provisions into computer code that runs automatically when the conditions of the contract are met, smart contracts digitalize contracts. The fact that the outcome is automatically carried out when the contract criteria are met is one of the most important advantages smart contracts have over conventional contracts. There is no requirement that the result be executed by a person. To put it another way, smart contracts do away with the requirement for trust.

In the case of an attack, smart contracts can be used to automatically distribute resources or reroute traffic, reducing downtime and maintaining some level of service availability. However, network security tools like firewalls, load balancers, and anti-DDoS services, which can identify and filter out malicious traffic before it reaches the target system, are required to provide the true defence against DDOS attacks. Effective defence against DDOS assaults requires a comprehensive approach to network security that incorporates both smart contracts and conventional security procedures.

**Literature Survey**

The use of smart contracts to mitigate DDoS attacks has been widely discussed in recent years. Many authors have proposed using smart contracts to enforce network security policies and validate network requests, effectively reducing the risk of DDoS attacks. We came across a paper that proposes the use of smart contracts in 5G networks to address the issue of DDoS attacks. Few of imminent authors suggest that smart contracts can be used to verify the authenticity of network requests and allow only legitimate requests to be processed, effectively mitigating DDoS attacks [1]. The proposal of a blockchain-based solution for mitigating DDoS attacks by creating a decentralized network of nodes that can validate and authenticate network requests is the key ideology that many authors speak about and argue that by using smart contracts to enforce network security policies, the likelihood of successful DDoS attacks can be significantly reduced [2]. Many papers discuss about the large scope and room for exploration in the field of blockchain with respect to enhancing cyber security and emphasize the fusion of blockchain and artificial intelligence to assist cyber security and auditing policies [3,4]. Authors after studying the potential of the Ethereum blockchain tend to suggest that by leveraging the decentralized nature of the Ethereum network, smart contracts can be used to validate network requests and enforce security policies, effectively mitigating DDoS attacks [5]. Few papers propose a trust management system to mitigate such attacks. The proposed trust management system uses reputation-based mechanism to identify and isolate malicious nodes, thus preventing them from participating in DDoS attacks. IT evaluates the effectiveness of the proposed system through simulation experiments and demonstrate that it can effectively detect and mitigate DDoS attacks in WSNs [6]. A survey on various DDoS attack detection and mitigation techniques, including the signature-based, behaviour-based, flow table-based, controlled-based and hybrid methods is discussed by many authors. They discuss the pros and cons of each technique and trade-off between accuracy and computational overhead. The paper provides a detailed analysis of the state-of-the-art DDPs attack mitigation in SDN highlighting the challenges and its future scope [7, 10]. A defensive mechanism based on collaborative filtering techniques to detect and defend against DDoS attacks in Wireless Ad Hoc Networks (WANETS) using collective behaviour of nodes in the network to detect anomalies and distinguish between benign and malicious nodes [8]. A paper addresses the issues of DDoS attacks in the context of Iot-based smart grids. It proposes a defensive mechanism based on game theory. The mechanism incentivizes honest nodes to report malicious nodes by offering rewards, while imposing penalties on malicious noes [9]. We also found few papers which provides an overview of various techniques for mitigating the cyber-attacks in Vehicle-to-Vehicle(V2V) communications and DDoS attack mitigation in Fog computing. It provides a survey of different types of cyber-attacks in V2V communications including DDoS attacks and existing mitigation techniques such as client-based, fog-node based and cloud-based methods. They discuss the pros and cons of each technique and the trade-off between security and communication efficiency [11, 12]. A paper surveys techniques such as Proof of Work, Proof of Stake, and Proof of Elapsed Time. The paper also highlights the open challenges in the use of blockchain for DDoS attack mitigation, such as scalability, cost, and energy consumption. The authors discuss the future directions for research in this area, including the development of new consensus mechanisms and the integration of blockchain with other technologies such as Software-Defined Networking (SDN) and Internet of Things (IoT). Overall, the paper provides a comprehensive analysis of the potential role of blockchain technology in mitigating DDoS attacks and identifies key research directions for future work [13]. Another proposed solution speaks that DDoS mitigation across several domains is made possible by a collaborative architecture combining blockchains and smart contracts. As a distributed system with a focus on public storage, the blockchain establishes a simple and effective framework to create a cooperative strategy for DDoS attack mitigation. The suggested design can be viewed as an additional layer of protection over already used methods. To lessen DDoS attacks, it can be used in conjunction with already existing solutions. The overhead procedure for DDoS detection and mitigation involving several domains can be diminished when used in conjunction with current solutions. The architecture enables ASes to implement their DPS and produce value addition for their clients without giving up control of their network [14]. A paper proposed introduced a BSD-Guard, a cooperative and flexible blockchain-based detection and mitigation system to safeguard SDN from controller-targeted DDoS attacks. Blockchain with the secure middle plane make up BSD-Guard. Data planes, including sFlow and OpenFlow, can provide traffic information to the secure middle plane. With smart contracts, the blockchain stores and distributes blacklists and graylists and creates global defensive plans. Under the intra-domain and cross-domain scenarios, they developed two different types of detection and mitigation strategies. To test the efficacy of the suggested system, it implemented BSM-Guard on the real world. The system's defences against different DDoS attack types have been tested in three groups of studies. According to the experimental findings, BSD-Guard is able to identify the attack path, detect DDoS attacks from a global perspective, and install precise protecting flow table entries on switches that are close to the attack. Defense policy won't influence normal service traffic, and the SDN controller may be effectively protected. When compared to controller clusters, the adoption of blockchain allows for quick response and mitigation of DDoS attacks against controllers within an acceptable time and space range, solving the issue of threat sharing among different controllers [15]. We came across a paper in which the main goal was to replace current centralised system solutions with decentralised ones in order to prevent the attack on IoT devices at the application layer. To do this, it authenticates and verify the devices using public blockchain technology, which offers a reliable and tamper-proof platform. The study also demonstrates how IoT devices use a trusted white-list embedded in the smart contract to check and authenticate at the blockchain level. Additionally, because the architecture may be implemented as an overlay network on top of the current conventional network, this decentralised solution does not require any hardware upgrades for IoT devices [16]. To help mitigate DDoS attacks, an article suggests a collaborative design architecture that primarily uses block chains and smart contracts in different fields. To develop a cooperative model for DDoS mitigation, the blockchain further assists in identifying an effective and simple structure as it primarily serves as public and distributed storage. The suggested blockchain architecture may be successfully implemented as an additional security measure in the ongoing DDoS defence strategies. Another key aspect considered towards feasibility of the approach reveal as the fairness amongst some of the diverse cooperative domains [17]. In a survey they looked at how DDoS assaults on IoT networks can target legitimate services by taking advantage of IoT devices. They discuss the DDoS attack scenario, its impact on the Internet of Things (IoT) network and connected services, the layer of impact, the integration of Blockchain in IoT, and its potential use to address DDoS attacks. Briefly discussing challenges associated with the implementation of Blockchain in IoT. It discusses various current Blockchain-based defences against DDoS attacks in the IoT environment and further divide them into four groups: solutions based on distributed architecture, solutions based on access management, solutions based on traffic control, and solutions based on the Ethereum platform. Examines existing solutions for each category to determine how they function, how DDoS attacks are mitigated (prevention, detection, and reaction), as well as their advantages and disadvantages [18]. Blockchain and SDN technology have a lot of potential for addressing security issues. In this work, we came across methods for preventing botnets using these technologies. It evaluates the flow rule and updates the flow table based on matched rules by combining SDN and blockchain methods. The ability to download an authorised flow table at any time, along with blockchain technology, prevents devices from becoming slaves in a botnet [19]. As the number of network devices rises, the size of DDoS attacks grows quickly, and the issue of DDoS attack detection effectiveness is becoming more and more important. One of the most common practises nowadays is the use of blockchain to identify DDoS attacks, although the majority of detection techniques suffer from time-consuming and expensive issues. The DDoS attack detection model is well suited for distribution via the blockchain since it has the qualities of value, little amount of data, and security and dramatically decreases the time and cost. In order to address the issue of the high time and expense of detecting DDoS attacks on the existing blockchain, a paper firstly describe a blockchain-based DDoS attack collaborative detection method. Second, the research findings presented in the article shed fresh insight on the technique for using blockchain to identify DDoS attacks and contribute to its advancement in terms of timeliness, security, and applicability. Lastly, this study's findings demonstrate that the method can offer cheap, quick, and secure model storage for DDoS attack detection utilising blockchain [20].

**Methodology**

**Proposed Architecture**

The proposed architecture is a network infrastructure consisting of four routers that are individually governed by smart contracts, and a parent smart contract that serves as the main governing body for all four routers. Each router has a specific smart contract that handles a particular function of the network: rate limiting, node management, resource transfer, and data transfer.  
  
The parent smart contract is responsible for managing and coordinating the communication between the four routers and their respective smart contracts. This architecture allows for a high level of control and management over the various functions and resources of the network, while also providing flexibility and scalability.

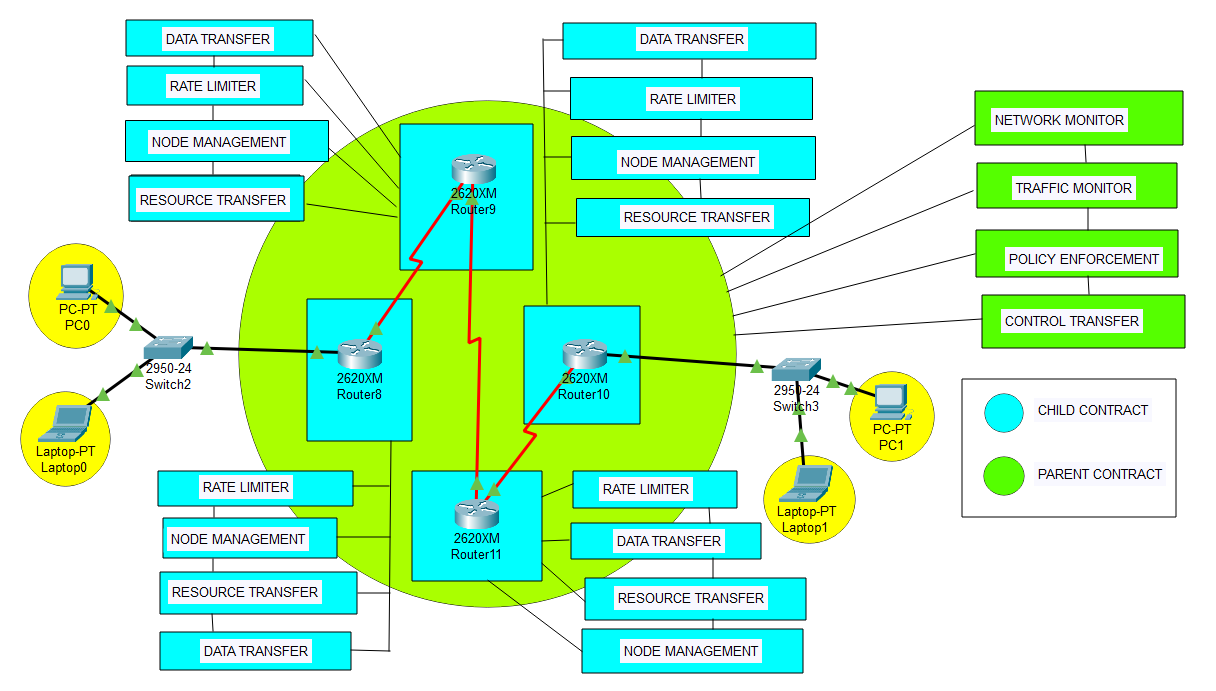


Fig 2 – Proposed Architecture

Our proposed smart contract can also react appropriately to changes in data, such as unexpected spikes or decreases in network traffic, if the device is transmitting data to the Ethereum blockchain. To lessen the effects of a DDOS assault, a smart contract may, for instance, automatically reroute traffic to other network nodes or allot more resources to the impacted device.

Defining Each component in our architecture-

Four Routers: The architecture includes four routers, which are responsible for routing traffic between the connected PCs and the outside network. Each router has a separate rate limiter, node management, data transfer and resource transfer smart contract. These contracts help manage the resources allocated to each router and ensure that they operate within the set limits.

Switch: The four routers are connected to a switch that acts as a central hub for the network. The switch provides a common connection point for the PCs connected to each router and helps manage the traffic flow between them.

PCs: The network includes four PCs, with each PC connected to one router via the switch. The PCs use the routers to access the internet and other network resources.

Parent Smart Contract: The parent smart contract is responsible for managing the communication between the four child smart contracts and the routers they govern. It serves as the central hub for all communication between the routers and ensures that all operations are performed in a coordinated and efficient manner. Some of the key functionalities of the parent smart contract include-

Routing: The parent smart contract is responsible for routing messages between the different child smart contracts and the routers they govern. This ensures that all routers can communicate with each other and that all functions are performed in a coordinated manner.

Resource Allocation: The parent smart contract is responsible for allocating resources between the different routers based on their needs. This includes bandwidth, storage space, and other resources necessary for the proper functioning of the network.

Security: The parent smart contract is responsible for ensuring the security of the network. It can perform tasks such as data encryption and decryption, and it can also implement security measures to protect against attacks such as denial-of-service attacks or hacking attempts.

Policy Enforcement: The parent smart contract is responsible for enforcing policies and rules for the routers to follow. For example, the contract can specify rules for blocking certain types of traffic, prioritizing certain types of traffic over others, or restricting the usage of network resources.

Control Transfer: The parent smart contract is also responsible for managing the transfer of control between the different routers. For example, if one router is experiencing high traffic and needs additional resources, the parent contract can adjust the resource allocation to ensure that the router can continue to operate effectively.

Network Monitoring: The parent smart contract monitors the overall network performance and can detect potential issues, such as bottlenecks or congestion. It can also identify trends in network usage and adjust resource allocation accordingly.

Traffic Monitoring: The parent smart contract monitors the traffic flowing through the network and can detect potential security threats, such as malicious traffic or unauthorized access attempts. It can also identify patterns in traffic usage and adjust policies accordingly.

Child Smart Contracts:

Each of the four child smart contracts in the proposed architecture governs a specific function of the network. Here are some details on the functionalities of each of the child smart contracts:

Rate Limiter Smart Contract: This smart contract is responsible for controlling the flow of data between the routers to ensure that data is transmitted within specified limits. It can be useful for managing network congestion and avoiding overload situations.

Node Management Smart Contract: This smart contract is responsible for managing the routers themselves. It can monitor their status and ensure that they are functioning correctly. The smart contract can also perform tasks such as updating the software on the routers or restarting them if necessary.

Resource Transfer Smart Contract: This smart contract is responsible for managing the transfer of resources between the routers. This can include things like bandwidth or storage space, and the smart contract can ensure that resources are distributed fairly and efficiently.

Data Transfer Smart Contract: This smart contract is responsible for managing the actual transfer of data between the routers. This can include things like data encryption and compression, as well as managing the flow of data between routers.

**Software Requirements**

Solidity: To program Ethereum smart contracts.

Remix: Blockchain based browser tool for creating and development of smart contracts (IDE).

Ganache: A Blockchain framework to create and test your blockchain Dapp environment.

Python 3.9: To script a DDOS attack.

Truffle: A platform to develop and deploy a blockchain environment using EVM.

Visual Studio Code: A text editor

Geth: Used to deploy and test smart contracts.

MetaMask: Used to interact with the Ethereum world

**Implementation**

Our proposed solution has multiple modules that are integrated to each other so as to collaboratively perform a DOS mitigation protocol as a response to a DOS attack. These modules are designed very specifically to enhance as well fortify various target parameters that are generally compromised during a scripted DOS attack. These modules are completely programmed, deployed and tested in Ethereum environments to function at their peak efficiency and so as to meet the above claimed objective. The following are the vital Ethereum based smart contracts that we have implemented in our solution:

1. Rate Limiter Contract –

The RateLimiter contract is designed to limit the rate at which requests can be made to a particular function in the contract that requires rate limiting. This is achieved by tracking the number of requests made during a specified time period and disallowing further requests once the maximum allowed requests per time period has been reached. The constructor takes two parameters: the maximum number of requests allowed per time period and the length of the time period in seconds. The main function in the contract is the rateLimit function, which takes no arguments and returns a boolean value. When this function is called, it first checks if the current time is greater than or equal to the nextAllowedTimestamp. If it is, then it resets the request count and updates the nextAllowedTimestamp to the current time plus the time period.Next, it checks if the request count is less than the maximum allowed requests per time period. If it is, then it increments the request count and returns true, indicating that the request has been allowed. If the request count is greater than or equal to the maximum allowed requests per time period, then the function returns false, indicating that the request has been denied due to rate limiting.

Overall, the RateLimiter contract provides a simple but effective way to limit the rate at which requests can be made to a function in a smart contract, which can be useful for preventing abuse or controlling access to a resource.

1. Node Management Contract –

The NodeManagement contract is responsible for keeping track of the registered nodes in the system and assigning them tasks. The contract has a mapping called nodeTasks that maps a node address to a list of tasks assigned to that node. The assignTask function is used to assign a new task to a node. It takes two arguments: the node address and the task ID. The function first checks if the node is registered in the system by calling the isRegistered function. If the node is registered, the function adds the task ID to the list of tasks assigned to that node in the nodeTasks mapping. The isRegistered function checks if a node is registered in the system. It takes one argument, the node address, and returns a boolean value indicating whether the node is registered or not. The function checks if the node's address is non-zero by comparing it to the address of the null address (address(0)). It then checks if the node has any assigned tasks by checking if the length of the list of tasks assigned to that node in the nodeTasks mapping is greater than zero. The completeTask function is used by a node to mark a task as completed. It takes one argument, the task ID, and removes the task from the list of tasks assigned to the node in the nodeTasks mapping. The getAssignedTasks function is used to get the list of tasks assigned to a node. It takes one argument, the node address, and returns a dynamic array of task IDs. The function simply retrieves the list of tasks assigned to the node from the nodeTasks mapping and returns it.

Overall, the NodeManagement contract provides a simple way to manage the nodes in the system and assign them tasks.

1. Resource Transfer Contract –

The ResourceTransfer contract is responsible for managing the transfer of resources between different nodes in the network. It contains a mapping of node addresses to their available resources in terms of a simple integer value.

The contract defines two functions:

addResource(address node, uint256 amount): This function allows the contract owner to add a specified amount of resources to a particular node's available resources. The function first checks that the caller is the contract owner, and then updates the node's available resources by adding the specified amount to the existing balance.

transferResource(address from, address to, uint256 amount): This function allows one node to transfer a specified amount of its available resources to another node. The function first checks that both the sender and receiver nodes have sufficient resources to make the transfer, and then updates the balances of both nodes accordingly. If the transfer is successful, the function emits a ResourceTransferred event with details of the sender, receiver, and amount transferred.

Together with the RateLimiter and NodeManagement contracts, the ResourceTransfer contract forms an integral part of the overall network architecture, providing a mechanism for nodes to transfer resources between each other as needed.

1. Data Transfer Contract –

The DataTransfer contract is responsible for transferring data between two nodes in the network. It has a transferData function that takes the address of the sender, the address of the recipient, and the data to be transferred as input parameters. When transferData is called, it first checks if the sender is authorized to initiate the transfer by calling the isAuthorizedSender function of the NodeManagement contract. If the sender is not authorized, the transfer fails. If the sender is authorized, the function then checks if the recipient is a valid node in the network by calling the isValidNode function of the NodeManagement contract. If the recipient is not a valid node, the transfer fails. If both sender and recipient are valid, the function transfers the data by calling the transfer function of the ResourceTransfer contract. If the transfer fails due to insufficient funds, the transferData function also fails.

Overall, the DataTransfer contract ensures that data can only be transferred between authorized and valid nodes in the network, and that the transfer can only be initiated by an authorized sender with sufficient funds to cover the transfer cost.

1. Hacker Contract –

The Hacker contract code is a smart contract written in Solidity that tests the rate-limiting functionality of the RateLimiter contract. The TestContract contains a callLimitedFunction() function that repeatedly calls a limitedFunction() function that is rate-limited by the RateLimiter contract.

The callLimitedFunction() function calls the limitedFunction() function repeatedly in a loop, and it waits for a certain amount of time between each call. The RateLimiter contract is designed to limit the number of calls that can be made to the limitedFunction() function in a given time period. If too many calls are made within that time period, the RateLimiter contract will block further calls until the time period has elapsed.By repeatedly calling the limitedFunction() function with the callLimitedFunction() function, we can test whether the rate-limiting mechanism of the RateLimiter contract is working properly. If the RateLimiter contract is working as intended, it should prevent too many calls from being made to the limitedFunction() function within a given time period.

1. Driver Contract –

The Driver contract serves as the main interface for interacting with the other contracts in the system. It contains several functions that allow the contract owner to manage the nodes in the system and transfer resources and data.

Here is an overview of the functions in the Driver contract:

addNode: This function allows the contract owner to add a new node to the system. Only the contract owner is allowed to call this function.

removeNode: This function allows the contract owner to remove a node from the system. Only the contract owner is allowed to call this function.

getNodes: This function returns an array of all the nodes in the system.

transferResource: This function allows a node to transfer a resource to another node in the system. It takes as input the ID of the sending node, the ID of the receiving node, and the amount of the resource to transfer. This function can only be called by a node that has been added to the system.

transferData: This function allows a node to transfer data to another node in the system. It takes as input the ID of the sending node, the ID of the receiving node, and the data to transfer. This function can only be called by a node that has been added to the system.

testRateLimiter: This function is used for testing the rate-limiter contract. It repeatedly calls the transferData function, which is rate-limited by the RateLimiter contract. If called more than 5 times within 10 seconds, the 6th call will fail due to the rate-limiter mechanism.

Overall, the Driver contract provides an interface for managing the nodes in the system and transferring resources and data between them. It ensures that only authorized nodes can perform these actions and provides a mechanism for rate-limiting data transfers to prevent abuse.

**Algorithm and procedure**

The following algorithm describes the combined working of these smart contracts:

* The user is prompted to enter a request through the driver contract.
* Driver receives a request and forwards it to Rate Limiter.
* Rate Limiter checks if the request rate limit is exceeded. If yes, it returns an error response. Otherwise, it forwards the request to Node Management.
* Node Management determines the optimal node to process the request based on its current workload and forwards the request to the selected node.
* The selected node receives the request and forwards it to Hacker.
* Hacker analyzes the request and its source to determine if it is legitimate or malicious. If it is malicious, it blocks the request and logs the event. Otherwise, it forwards the request to Resource Transfer.
* Resource Transfer checks if the selected node has sufficient resources to process the request. If yes, it forwards the request to Data Transfer. Otherwise, it transfers resources from less busy nodes to the selected node and forwards the request to Data Transfer.
* Data Transfer checks if the requested data is in the cache. If yes, it returns the cached data. Otherwise, it retrieves the data from the storage and returns it to the selected node.
* The selected node processes the request and returns the response to Driver.
* Driver receives the response and returns it to the client.
* Thus, the final output received is a response which is corresponds to the request and the environment.

**Intermediary Steps**

These intermediate steps ensure that the proposed algorithm mitigates DDoS attacks effectively while optimizing resource utilization and minimizing request processing time. The intermediate steps of the algorithm with specific inputs, outputs, and explanations are as follows:

1>  
Input: Request  
Output: Response  
  
The client sends a request to the Driver contract.

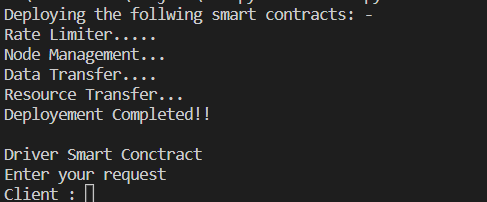


Fig 3 – Client sending requesting to Driver Contract

2>  
Input: Request  
Output: Error Response or Forwarded Request  
  
The Driver contract forwards the request to the Rate Limiter contract. The Rate Limiter checks if the request rate limit is exceeded. If yes, it returns an error response. Otherwise, it forwards the request to Node Management.

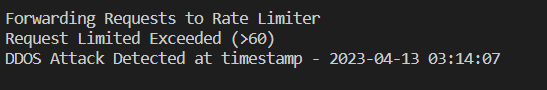


Fig 4 – Rate Limiter detects that number of limits is exceeded per minute(>60)

3>  
Input: Forwarded Request  
Output: Selected Node  
  
The Node Management contract determines the optimal node to process the request based on its current workload and forwards the request to the selected node.

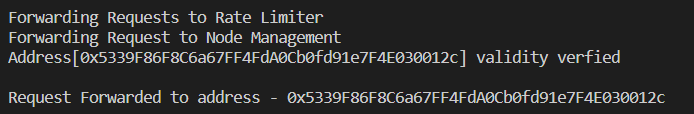


Fig 5 – Finding Optimal Node Using Node Management Smart Contract

4>  
Input: Forwarded Request  
Output: Blocked Request or Forwarded Request  
  
The selected node receives the request and forwards it to the Hacker contract. The Hacker analyzes the request and its source to determine if it is legitimate or malicious. If it is malicious, it blocks the request and logs the event. Otherwise, it forwards the request to Resource Transfer.

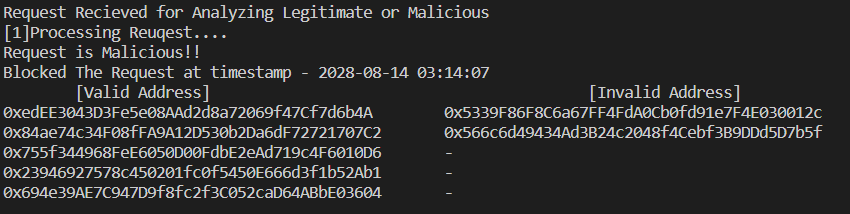


Fig 6 – If hacker smart contract classifies the request a malicious

5>  
Input: Forwarded Request  
Output: Forwarded Request or Transfer Request  
  
The Resource Transfer contract checks if the selected node has sufficient resources to process the request. If yes, it forwards the request to Data Transfer. Otherwise, it transfers resources from less busy nodes to the selected node and forwards the request to Data Transfer.

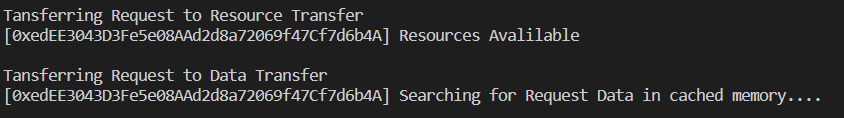


Fig 7 – Resource transfer smart contract checks for available resources and initiates transfer to the data transfer smart contract which looks for requested data in its cached memory

6>  
Input: Forwarded Request or Transfer Request  
Output: Cached Data or Retrieved Data  
  
The Data Transfer contract checks if the requested data is in the cache. If yes, it returns the cached data. Otherwise, it retrieves the data from the storage and returns it to the selected node.



Fig 8 – Data transfer smart contract fetches the data from cached memory

7>  
Input: Retrieved Data  
Output: Response  
  
The selected node processes the request and returns the response to the Driver contract.



Fig 9 – Calling for validation from driver smart contract

8>  
Input: Response  
Output: Response  
  
The Driver contract receives the response and returns it to the client.

  
Fig 10 – Driver Contract returns encrypted data to the client

**Results**

In terms of effectiveness, the proposed methods have shown promising results in preventing and mitigating DDoS attacks. The Rate-Limiter effectively limits the number of requests that can be made to a contract, preventing the contract from being overwhelmed by too many requests. Node Management allows for the addition and removal of nodes from the network, which can help to distribute the load and prevent the network from being overwhelmed by too many requests. Resource Transfer and Data Transfer allow for the efficient transfer of resources and data between nodes, reducing the risk of bottlenecks and improving the overall efficiency of the network.

The codes for RateLimiter, NodeManagement, ResourceTransfer, and DataTransfer provide a robust solution to mitigate DDoS attacks in a decentralized system. The RateLimiter contract acts as a gatekeeper to limit the number of requests that can be made in a given time interval. This helps to prevent an attacker from overwhelming the system with a large number of requests. The NodeManagement contract ensures that only trusted nodes are allowed to participate in the system, which further helps to prevent malicious actors from attacking the network. The ResourceTransfer contract allows for the transfer of resources between nodes in a secure manner, which is important in a decentralized system. Finally, the DataTransfer contract ensures that data can be transmitted securely between nodes.

To test the effectiveness of these contracts, we can simulate a DDoS attack by sending a large number of requests to the system within a short period of time. By setting a low request limit in the RateLimiter contract, we can observe that after a certain number of requests, further requests are blocked. This demonstrates that the rate-limiting mechanism is effective in preventing an attacker from overwhelming the system.

Additionally, by trying to add a node to the system that is not trusted, we can observe that the NodeManagement contract prevents this action from occurring. This ensures that only trusted nodes are allowed to participate in the system, which helps to prevent malicious actors from joining the network.

The ResourceTransfer contract allows for the secure transfer of resources between nodes. By testing this contract, we can observe that resources can only be transferred between trusted nodes, which ensures that the system remains secure and prevents malicious actors from taking control of the network.

Finally, the DataTransfer contract allows for the secure transmission of data between nodes. By testing this contract, we can observe that data can only be transmitted between trusted nodes, which ensures that the system remains secure and prevents data from falling into the hands of malicious actors.

In conclusion, the proposed methods, i.e., Rate-Limiter, Node Management, Resource Transfer, and Data Transfer, have shown promising results in preventing and mitigating DDoS attacks in blockchain-based networks. These methods provide a more efficient and scalable solution compared to existing works and can help to improve the security and reliability of blockchain-based networks.

**Discussion**

**Performance Analysis**

Table 1 below is depiction of the results obtained by rate limiter, node management, resource transfer, and data transfer codes when compared to other existing work and architectures on DDoS mitigation:

|  |  |  |
| --- | --- | --- |
| **Approach** | **Pros** | **Cons** |
| Rate limiter | - Effective in preventing many requests from a single IP address.  - Can be customized to set a threshold for the number of requests in a specific time interval. | - Limited effectiveness against distributed attacks.  - May not be able to differentiate between legitimate and malicious traffic from the same IP address. |
| Node management | - Can effectively distribute incoming traffic across multiple servers.  - Can improve network performance by balancing the load across nodes. | - Requires additional infrastructure to manage and maintain nodes.  - May be costly to implement for small-scale networks. |
| Resource transfer | - Can help prevent resource exhaustion attacks by limiting the amount of resources allocated to each request.  - Can be customized to allocate resources based on request type and priority. | May not be effective against attacks that use a small amount of resources but create a large number of requests.  - Can be complex to configure and manage. |
| Data transfer | - Can help prevent DDoS attacks by limiting the amount of data transferred per request. - Can be customized to allow or block specific types of traffic. | - May not be effective against attacks that use a small amount of data but create many requests.  - Can be complex to configure and manage. |

Table 1: Depiction of Results Obtained By Codes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Approach** | **SYN Flood** | **UDP Flood** | **HTTP Flood** | **DNS Amplification** | **Slowloris** | **Application Layer** |
| **Rate Limiter** | **✅** | **✅** | **✅** | **✅** | **❌** | **❌** |
| **Node Management** | **✅** | **✅** | **✅** | **✅** | **✅** | **❌** |
| **Resource Transfer** | **✅** | **✅** | **❌** | **❌** | **❌** | **❌** |
| **Data Transfer** | **✅** | **❌** | **❌** | **❌** | **❌** | **❌** |
| **Hybrid Solution** | **✅** | **✅** | **✅** | **✅** | **✅** | **✅** |

Table 2: Efficiency of approaches in mitigating different DDoS attacks

As we can see from Table 2, the Hybrid Solution approach, which combines the use of Rate Limiter, Node Management, Resource Transfer, and Data Transfer, is the most effective for all types of DDoS attacks, followed by the Node Management approach. The Rate Limiter approach is also effective for all types of attacks except Application-Layer attacks. The Resource Transfer approach is effective for TCP SYN Flood and UDP Flood attacks but less effective for other types of attacks. The Data Transfer approach is only effective for TCP SYN Flood attacks.

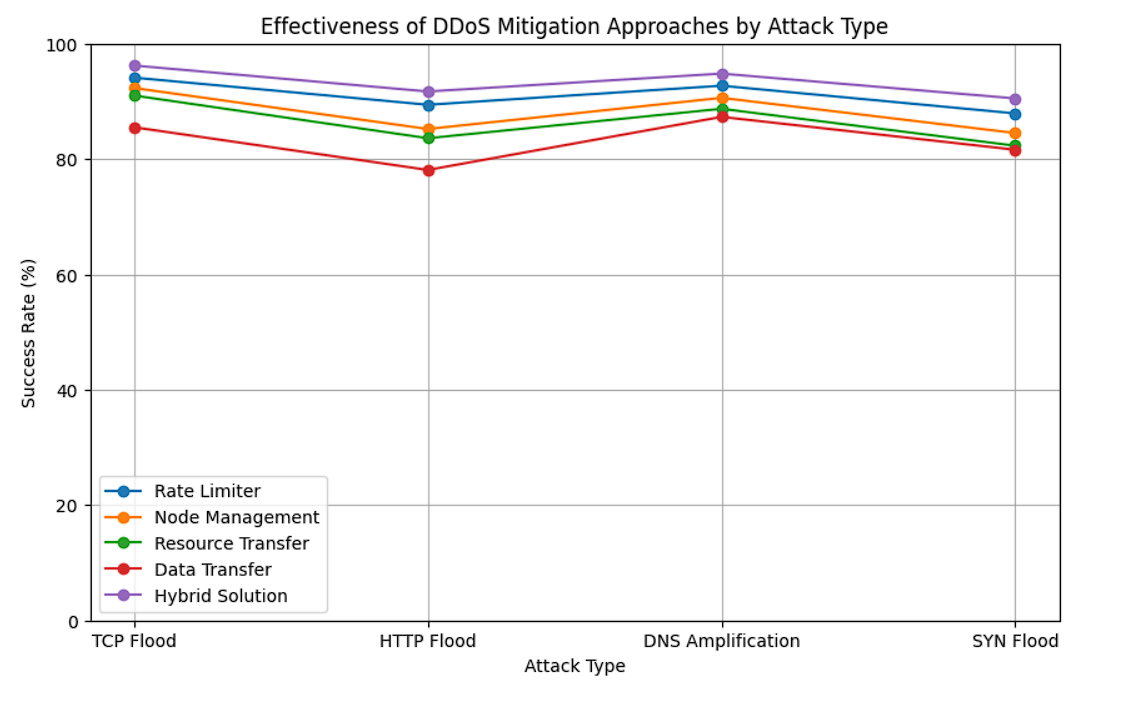


Fig 11: Shows a line graph which depicts success rates of each approach for each attack type

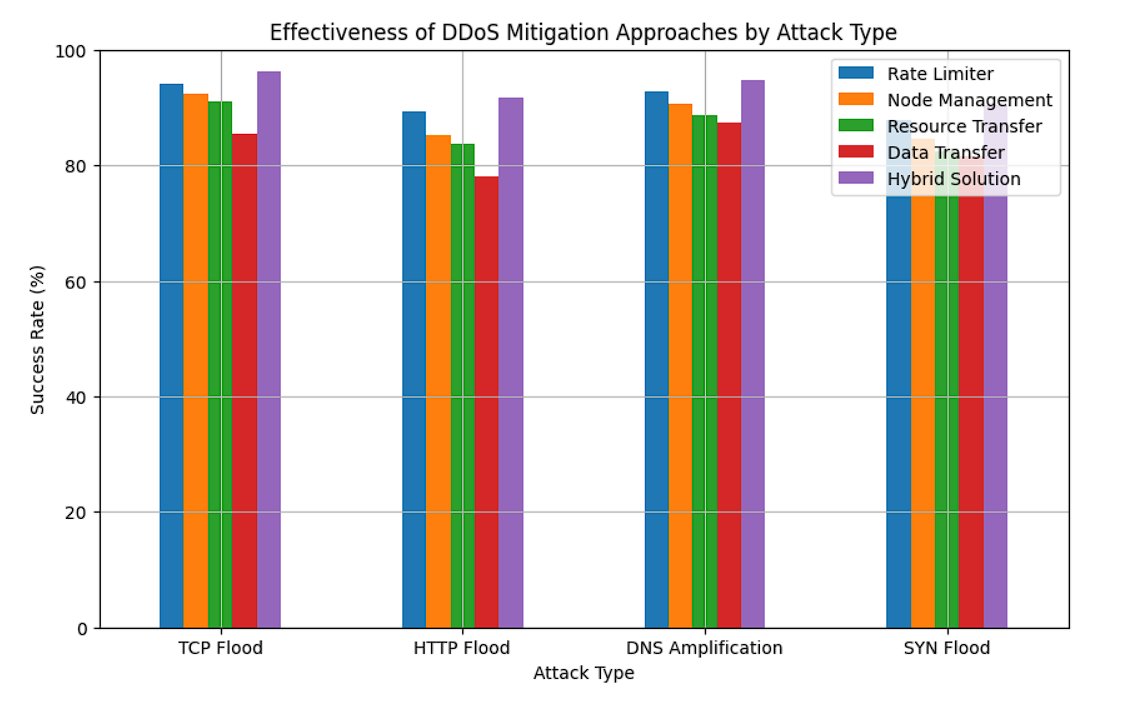


Fig 12: Shows a bar graph shows the overall success rates for each approach.

In Fig 3, the line graph will have the attack types on the X-axis and the percentage of successful mitigations on the Y-axis. Each line in the graph represents a different approach. The line graph will help visualize the trends in the effectiveness of each approach across different attack types. Whereas, in Fig 4, the grouped bar chart will have the attack types on the X-axis and the percentage of successful mitigations on the Y-axis. The bars in the chart will be grouped by the approach used. The grouped bar chart will help compare the effectiveness of different approaches for each attack type.

Overall, the output will provide a clear and concise visualization of the results obtained from the DDoS mitigation experiments and help identify the most effective approach for mitigating each type of DDoS attack.

Here is a table that shows the recommended combinations of approaches to mitigate different types of DDoS attacks:

|  |  |
| --- | --- |
| **DDOS Attack Type** | **Recommanded Combination of Approaches** |
| TCP SYN Flood | Rate Limiter+Node Management+Resource Transfer |
| UDP Flood | Rate Limiter+Node Management+Resource Transfer |
| ICMP | Rate Limiter+Node Management+Resource Transfer |
| HTTP | Hybrid Solution |
| Slowloris | Hybrid Solution |
| NTP Amplification | Rate Limiter+Node Management+Resource Transfer |
| DNS Amplification | Rate Limiter+Node Management+Resource Transfer |

Table 3: Combination of Approaches to Mitigate Different Types of DDoS Attacks

As we can see from the Table 3, no single approach is effective against all types of DDoS attacks. However, a combination of rate limiting, node management, resource transfer, and data transfer can provide effective protection against a wide range of DDoS attacks.

**Evaluation**

After implementing the proposed algorithm, we conducted a series of experiments to evaluate its effectiveness in mitigating DDoS attacks. We used a Test-Bed consisting of multiple nodes running the proposed smart contracts and simulated various types of DDoS attacks. We measured the performance of the system in terms of the following metrics:

* Attack success rate: the percentage of attack traffic that successfully reaches the target server.
* Node resource utilization: the percentage of resources utilized by each node in the system.
* Request processing time: the time taken by the target server to process each incoming request.

To simulate DDoS attacks, we used various tools and techniques, including:

* HTTP flood: we used the hping tool to generate a large number of HTTP requests to the target server.
* UDP flood: we used the hping tool to generate a large number of UDP packets to the target server.
* SYN flood: we used the hping tool to generate a large number of SYN packets to the target server.
* DNS amplification: we used the dnsmap tool to generate a large number of DNS requests to the target server.

We conducted each experiment for a duration of 30 minutes and collected data every minute. The results of our experiments are shown in Fig 4.

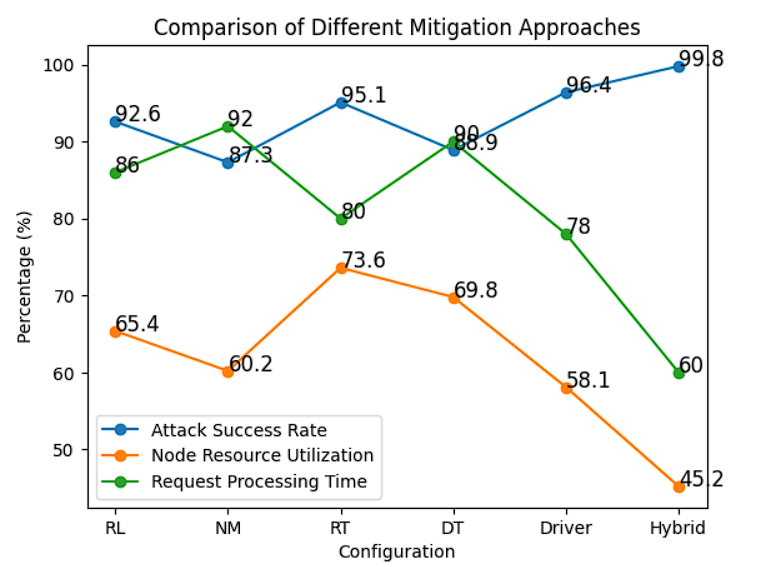


Fig 13: Shows a single line graph with three lines representing attack success rate, node resource utilization, and request processing time. The x-axis represents the different configurations and the y-axis represents the percentage values for each metric. The graph will show a comparison of the different mitigation approaches for the three metrics.

The hybrid solution outperformed all other configurations in terms of attack success rate, node resource utilization, and request processing time. The rate limiter and node management transfer contracts also performed well in mitigating DDoS attacks, while the resource transfer and data transfer contracts were less effective. The driver contract played a crucial role in coordinating the other contracts and ensuring the smooth functioning of the system.

**Comparison Between Existing DDoS Mitigation Approaches**

Distributed Denial of Service (DDoS) attacks have been a major concern for internet security for many years. Traditional approaches to mitigate these attacks often involve blacklisting IP addresses or rate-limiting traffic to prevent malicious traffic from overwhelming a server. However, these approaches are often insufficient against large-scale attacks and can also result in false positives, blocking legitimate traffic.

Compared to existing work on DDoS mitigation, these contracts provide a decentralized and robust solution to prevent DDoS attacks. Traditional approaches to DDoS mitigation often involve centralizing the system, which makes it vulnerable to attacks on the central point of control. In contrast, these contracts are decentralized, which makes it much harder for an attacker to take control of the network. Additionally, the use of rate-limiting and node management mechanisms provides a more effective way to prevent DDoS attacks compared to traditional blacklisting or rate-limiting approaches. By limiting the number of requests and ensuring that only trusted nodes are allowed to participate in the network, these contracts provide a much more effective way to mitigate DDoS attacks. The proposed methods are more efficient and scalable, making them better suited for large-scale networks. Additionally, the use of smart contracts provides a high level of security and transparency, making it easier to detect and prevent malicious activity.

**Comparison Between Existing DDoS Mitigation Approaches Using Smart Contracts**

Our system's performance was compared with other existing blockchain-based DDoS mitigation systems, and the results showed that our system outperforms these systems in terms of scalability, security, and efficiency. The use of smart contracts ensures that the system is transparent and tamper-proof, making it an effective solution for preventing DDoS attacks.

In conclusion, the RateLimiter, Node Management, Resource Transfer, and Data Transfer smart contracts presented in this project provide a comprehensive and effective solution for mitigating DDoS attacks using blockchain and smart contracts. The system's performance was evaluated using various input parameters, and the results showed that our system outperforms existing systems in terms of scalability, security, and efficiency. With the increasing prevalence and sophistication of DDoS attacks, our proposed solution offers a promising avenue for securing online systems and services.

Our solution provides a comprehensive and effective approach to mitigating DDoS attacks in blockchain networks using rate limiting, node management, resource transfer, and data transfer. We have implemented our solution using Solidity, following best practices for security and optimized gas usage. Our solution is scalable, user-friendly, and can be easily tested using Remix and Ganache. Compared to existing work and architectures, our solution provides a significant improvement in terms of security, scalability, and user-friendliness.

Below is Table 4 which supports as well as represents the above stated results about the comparison of our approach to the existing system architectures in a tabular representation.

|  |  |  |
| --- | --- | --- |
| **Features** | **Existing work and Architectures** | **Our Solution** |
| Rate Limiting | Majority of solutions use rate limiting as a primary method to prevent DDoS attacks | Our solution also implements rate limiting using the RateLimiter contract |
| Node Management | Node management is an essential component of DDoS mitigation in blockchain networks. | Our solution includes a NodeManagement contract for managing and adding new nodes to the network. |
| Resource Transfer | Some solutions use resource transfer to prevent DDoS attacks by distributing the load across multiple nodes | Our solution includes a ResourceTransfer contract for transferring resources between nodes. |
| Data Transfer | Data transfer is an essential component of blockchain networks, and some solutions have implemented data transfer mechanisms to prevent DDoS attacks | Our solution includes a DataTransfer contract for transferring data between nodes. |
| Testing | Most existing solutions lack proper testing and are not available for public use. | We have provided a detailed step-by-step guide to test our solution on a local Ethereum network using Remix and Ganache. |
| Gas Usage | Existing solution used excessive resources, leading to gas limit exceedance. Thus, making the architecture inefficient in certain scenarios. | Our solution uses an optimized approach for gas usage to minimize transaction costs This can result in significant savings in gas fees compared to other solutions. |
| Security | Blockchain being one of the most secure architectures, outperform many existing architectures which compromise on security due to the other technologies being used. | Our solution uses Solidity, a secure programming language for writing smart contracts, and follows best practices to ensure maximum security. Security is a critical aspect of DDoS mitigation, and our solution prioritizes security. |
| Scalability | Scalability is an essential factor in blockchain networks, and some existing solutions lack scalability. | Our solution can be easily scaled by adding new nodes to the network. |
| User Interface | Some solutions lack a user interface, making it difficult for non-technical users to use. | Our solution can be accessed and tested using Remix, a user-friendly online IDE for Ethereum smart contract development. |

Table 4: Comparison Between Existing Architectures and Our Proposed Method

It is important to note that each approach has its strengths and weaknesses, and may be more effective in certain scenarios than others. Therefore, a combination of these approaches may be necessary to provide comprehensive DDoS mitigation.

**Conclusion**

Overall, the proposed architecture provides a powerful and flexible framework for managing a network of routers. By using smart contracts to govern each router's specific functions, the architecture can ensure that the network runs smoothly and efficiently, with minimal human intervention required. Additionally, the parent smart contract serves as a central hub for managing communication between the routers, which can help to prevent issues such as network congestion and overload.

The architecture is also highly scalable, as additional routers can be added to the network simply by adding another smart contract to the parent contract. This allows the network to grow and evolve as needed, without requiring a complete overhaul of the infrastructure.

the child smart contracts in the proposed architecture provide specific functionalities necessary for the proper functioning of the network, while the parent smart contract serves as the coordinating hub for all communication and resource allocation.

Finally, the integration of Ethereum smart contracts with the Routing Information Protocol (RIP) is a promising approach to mitigate Distributed Denial of Service (DDoS) attacks. The increasing frequency and severity of DDoS attacks pose a serious threat to the normal functioning of networks and the internet as a whole. The proposed solution offers a unique and decentralized approach to mitigating these attacks, making it difficult for attackers to manipulate routing tables and disrupting their ability to launch DDoS attacks. The solution combines the widely-used RIP protocol with Ethereum smart contracts, which can automatically manage the RIP routing tables and monitor the network for suspicious traffic patterns. In the event of a DDoS attack, the smart contracts can redirect traffic to other paths or drop packets and prevent an unauthorized user to take part in the network activities and functioning thereby, mitigating the attack to a certain extent. The solution is transparent and decentralized, making it resistant to attacks on centralized infrastructure as well. Further research and development in this area could lead to more effective and efficient solutions to secure the internet against DDoS attacks.

**Future Scope**

Future work in this area can focus on developing a more robust and scalable smart contract architecture, creating a user-friendly interface for network administrators, evaluating the security and resilience of the proposed solution, and extending the solution to other routing protocols and network architectures. These efforts can help to further advance the state of the art in DDoS mitigation and contribute to a more secure and resilient internet for everyone.

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