As an outcome of several research studies, there are several statistical mechanisms to detect the intrusions in the network traffic on analyzing the source and destination IP address, detection based on the port degeneration values, destination decay and wavelet-based analysis, etc [4]. With the massive usage of cloud computing and IoT technologies, the model for DDoS attack has been changing frequently with the frameworks of computing. Design and development of the novel statistical models are time-consuming as it will not be able to sustain rapid and dynamic changes within the network. The major drawback observed while constructing the statistical model is that it is bounded towards a single application scenario and the range of complexity in building and maintain the model. In the context of resolving the problems of the statistical models in detecting and predicting DDoS attacks, the researchers have focused on the deep and machine learning algorithms to develop context-aware prediction models that are bounded to be less complex and high performance-centric. It is evident from various research studies that Machine learning algorithms have demonstrated high performance while adopting towards the dynamic changes within the network and predicting the network traffic along with the intrusions within the network.

Machine learning and deep learning algorithms have the ability to identify unconstrained information within massive amounts of data which draws the attention of various researchers to study the application of these strategies. Researchers in [2] have utilized the access patterns of various clients, flow size constrained to the network traffic and chronological behavior while devising machine learning models to classify abnormal network from a normal network in the circumstance of controlling the servers. The major advantage of machine learning models is that data is updated dynamically within the prediction model such that the changes within the network could be easily identified. Few studies evident that still there are few deficiencies while adopting machine and deep learning algorithms because of its substantial computational complexity. DDoS attack patterns vary from different network components. Primarily DDoS attacks involved in devastating the target remote server or network traffic towards the server could be categorized into three categories that include application-layer based attacks, Protocol level attacks, and Network traffic attacks.

The contribution of this article is threefold. Firstly, the attack patterns and characteristic features of DDoS attacks are analyzed to identify the common motivational aspects behind the attack. Secondly, a systematic review of various studies involved in the application of machine and deep learning algorithms are detailed. Further, an attempt of identifying research gap is made based on the evidence-based research to analyze the success rate machine and deep learning algorithms in the detection and prediction of DDoS attacks in an
unconstrained network environments.
The rest of the article is organized as follows: Systematic procedure of the review and research framework adopted for the review along with the procedure involved in the selection of the studies is detailed in Section 2. Section 3 provides details about various types of DDoS attacks while Section 4 summarizes the review of the various existing machine and deep learning models for detection and prediction of DDoS attacks Section 5 addresses the research gaps and open challenges based on the review results. Finally, Section 6 concludes the paper along with further research directions.

II. RESEARCH METHODOLOGY

This paper adopts the procedure of conducting a systematic literature review (SLR) from [5]. The main intention of conducting SLR is to execute a well-planned literature study in the context of answering the Research Questions that are framed at the initial stage of the study. SLR enables the researchers to discover, evaluate and amalgamate the research studies conducted by various network security researchers. The development of SLR includes the following process:

- Development of review protocol that includes complete procedure involved in conducting SLR of predicting DDoS attacks using the machine and deep learning applications.
- Enumerate the Research Questions based on the PICO search strategy [6] in the context of DDoS attacks.
- Primary and secondary selection strategy to filter the articles addressing the research questions.
- Synthesize the selected studies to answer the research questions.

![Figure 1: SLR Process [6]](image)

2.1 Research Questions

The most important step in the systematic review protocol is defining Research Questions (RQ’s). The streamline of the study is initially maintained by RQ’s. In the context of defining RQ’s, this article adopts a PICO strategy that involves various components that elevate the quality of the study. The research questions framed on addressing a DDoS attack are as follows:

- **RQ1** What are the various types of DDoS attacks that could be referred to as a major concern in the context of distributed networks?
- **RQ2** What are various existing machine learning algorithms devised to address DDoS attack prediction?
- **RQ3** What are the various tools and data sets utilized?
- **RQ4** How machine learning and deep learning techniques influence the research in the prediction of DDoS attacks

2.2 Search strategy

The intention of the systematic study is to discover, compare and classify the existing research studies within the class imbalance problems using a systematic procedure. Popular scientific databases like IEEE, SPRINGER, ACM, SCIENCE DIRECT and Google scholar libraries are utilized for the searching process using the following search strings in different combinations.

- DDoS Attacks OR Intrusion detection Systems OR Network Security
- Application layer attacks OR Network Traffic based attacks
- OR Protocol Attacks
- AND
- Distributed Computing OR Cloud Computing OR Internet of Things (IoT)
- AND
- Machine learning Algorithms OR Deep learning Algorithms OR Hybrid Mechanisms
- AND
- Systematic Study OR SLR OR Mapping Study OR Review

In the initial cases during the study using the above search string we have identified around 220 research papers in specific to the class imbalanced problems that are published in the past decade. Table 2 indicated different online mechanisms utilized for the process of searching relevant studies.

Table. 2 Various Scientific databases considered for SLR

| S.No | Database        | No. Of Papers |
|------|-----------------|---------------|
| 1    | IEEE            | 108           |
| 2    | ACM             | 10            |
| 3    | SPRINGER        | 42            |
| 4    | SCIENCE DIRECT  | 35            |
| 5    | GOOGLE SCHOLAR  | 25            |
|      | **Total**       | **220**       |

2.2.1 Preliminary selection

In the preliminary phase, of the selection, 300 related articles are extracted from the scientific databases using the search strings in which articles are scrutinized based on the relevancy of the title towards the problem statement and further the remaining are ignored. Additionally, the articles from the thesis, book chapters, short papers and papers communicated in non-English language are ignored from the study. The inclusion and exclusion criterion of the articles is made by analyzing the title, abstract and conclusion of the articles. Such that filtering of the appropriate articles is accomplished with relevance to the class imbalance problem.

Title: (DDoS attacks OR Intrusion detection systems OR Machine learning model OR Algorithm Centric techniques OR Application layer attack OR Deep Learning Model OR Network Attack OR Hybrid Mechanisms OR Network Traffic OR Software-defined networking OR Cloud Computing)

AND

Abstract: (Machine learning mechanisms OR Techniques and approaches of network security OR Deep Learning mechanisms)
2.2.2 Selecting the articles based on the Implementation details and Data sets Utilized

In this phase, we further analyze the quality of the articles based on the implementation details furnished in the article, such that the article is thoroughly examined to identify the algorithm utilized to resolve the DDoS attacks in classification along with its implantation with real-world dataset are considered for the review process. Further, the articles with a detailed description of the algorithm are considered based on the novelty of the technique. Based on the opinions and suggestions of the experts with experience in the process of conducting a systematic review in various domains, search strings are modified to be more focused on the topic and furnished above. Feedback from a team of research experts is considered to enhance the process of SLR. The detailed discussion of various algorithms, techniques, and approaches regarding the prediction of DDoS attacks is provided in section 3. The inclusion and exclusion criteria framed for the study selection as shown in table 3. Finally, 34 articles are considered for the review related to DDoS prediction and detection based on the inclusion and exclusion criteria.

Table 3. Inclusion and Exclusion Criteria

| Inclusion Criteria                                      | Exclusion Criteria                                      |
|---------------------------------------------------------|---------------------------------------------------------|
| Articles that include prediction and detection techniques associated with the machine and deep learning algorithms | Articles with an ambiguity in the context of the implementation of the proposed mechanisms |
| Articles prepared in the context of evidence-based research in predicting DDoS attacks with a clear representation of implementation details that includes datasets, tools, and mechanisms | White papers and Lecture notes regarding the prediction of DDoS attacks using the machine and deep learning techniques |
| Articles that are primarily implemented in the computer science domain | Articles are written in other than the English language |
| Articles that are written in the English language | |

III. CHARACTERISTICS AND CLASSIFICATION OF VARIOUS DDoS ATTACKS

The primary characteristic of the DDoS attack is gaining control over the network of remote servers in the context of launching an attack. Initially, malware is injected to the computer machines over the network which in turn transform each machine as an intruder through which the targeted server accessed using its IP address or Network traffic and various components of the network connection. This context may cause a situation in which the authenticated users will not be able to utilize the premium services enabled by the server. There are various types of DDoS attacks based on the network layer on which the attack was being launched. Classification of DDoS attacks is as follows:

a) Application Layer Attacks: The primary objective of the application layer attacks is to wear out the resources of the targeted server. This kind of attacks mainly focuses on the dynamic web pages that are generated by the server and in turn delivered to the client upon an HTTP request. Serving an HTTP request from the server side is considered as a complex process as it is involved in loading multiple sets of files based on the database transactions in the process of generating access to the web page.

![Figure 2: Classification of DDoS attacks](image)

b) Volumetric Attacks: This kind of attacks mainly concentrate on the congestion levels of the network in the context of the target server. The objective of this attack is to create and unnecessary congestion over the target servers network by means of disposing large amounts of data to the server over the network using various amplification techniques. The amount of traffic generated using volumetric attack will be able to create disruption over the server's network.

c) Protocol Attacks: These attacks mainly concentrate on exhausting the server resources interms of the processing speed. These attacks mainly concentrate on the network and transport layers through which it tries to exhaust the processing capacity of the servers as well as the middleware network resources that include firewall, load balancers, and networks switches. This attacks always try to make use of TCP handshake mechanism and IP protocol with a spoofed IP address to gain access to the target machine.

IV. REVIEW OF MACHINE LEARNING AND DEEP LEARNING APPROACHES IN PREDICTING DDOS ATTACKS

Detection and prediction techniques of DDoS attacks are broadly classified into four major areas that include soft computing, knowledge-based mechanisms, Statistical methods and Machine learning methods based on the research studies conducted by Prasad et al [8]. Further few research studies have categorized the detection methods based on DoS-misuse detection as well as anomaly detection. Table 4 Synthesises the information based on the different classes of DDoS attack prediction and detection mechanisms. IDS (Intrusion Detection System) that works based on the attack signatures require an individual administrator that concentrates on the pattern of the attack to predict and identify the attacks, in this scenario huge manpower is required for creating, deploying and testing the attack signatures over the network. Addressing this problems usage of machine learning algorithms [9] will automate the process of
Table 5. Categories of various techniques to detect DDoS attacks

| Category                        | Description                                                                 |
|---------------------------------|-----------------------------------------------------------------------------|
| Knowledge-based Mechanisms      | These methods intend to identify the attacks whose signatures are already aware and the same are used to track the patterns of the new attack |
| Machine Learning(ML) based Mechanisms | ML and advanced learning mechanisms like deep learning (DL) effectively predict the hidden patterns of network information to predict and classify various attacks |
| Statistical Methods             | Modelling the statistical patterns of the normal attacks and use these inferences to classify the dynamically generated network traffic to predict network traffic based attacks |
| Soft Computing Mechanisms       | Derive learning patterns based on the optimization techniques to optimize network traffic for predicting attacks |

The recent studies presented by Gil and Poletto [10] Details about the statistical technique derived based on a multi-level tree that analyses the online packet statistics in this context the researcher had was you made that the bracket rates in between the hosts are constrained to be proportional to each other.

4.1 Machine Learning and Deep Learning

Mechanisms to predict Application layer DDoS Attacks.

Application layer DDoS attacks generally deal with the concept of botnets. Most of the DDoS attacks were launched based on the open-source tools which in turn different organizations will not be able to identify the traces of attacks. The researchers in [11] have analyzed the context of coding that lies behind various popular DDoS attacks that include agobots, SpyBot, SDbot, and Rbot. The main objective here is to gain knowledge with respect to the patterns of various DDoS attacks that would be utilized to mitigate the effect of future DDoS attacks. Botnet based DDoS attacks and its effect was studied by Almariet.al [12] which mainly focused on the application layer that may cause the security damage to their business through which it is identified to be a major concern in the context of the business. Possible solutions and further research directions have been summarised in this research. Most widely used method to defend DDoS attack is Pushback method as this method utilizes the concept of congestion control. This method mainly comprised of selective drop as well as detection stages through which it could efficiently defend application-layer attacks. Further, the researchers in [13] have extended the pushback technique based on the puzzle-solving method in which the target server will send a puzzle over the network to the client to authenticate whether the reliable client has been connected to the server. The attack patterns and principles are evaluated and presented in [14] Through the study of existing DoS attacks and their patterns that label is the distributed and wireless network systems.

The analysis of the botnet based attack similarity in gaining access to the web application was discussed in detail in [15]. SVM (Support Vector Machine) based mechanism was proposed to detect these attacks based on the pattern of requests generated by the clients and analyzed the context thoroughly based on the request rhythm matching algorithm. Addressing the problem of the similarity of information flow over the network by similar bots Xiao et al in [16] have proposed a KNN based algorithm that identifies the network traffic generated by similar bots. An artificial neural network-based Radial Basis Function (RBF) is utilized to detect the features of the patterns through which the router will be able to classify the network traffic as into the category of normal or attack. In this context, if the input network traffic is analyzed as an attack based pattern then it is filtered and triggers the alarm based on the source IP address.

Further, in [17], the authors have utilized a data mining based mechanism in which a prior association and FCM clustering algorithms are used to define a threshold value to detect an attack based on the extraction of the network traffic as well as the network packet protocol. Authors in [18] have proposed a mechanism based on the grey relational analysis and decision tree system in which they have utilized at most 15 diverse attributes that intern monitor and compile the input and output traffic using TCP ACK and SYN flag rate to analyze the pattern. The main context of using decision tree here is to identify the abnormal flow of the traffic.

4.2 Detection and Prediction of Volumetric attacks

DRDoS attacks are a category of DDoS attack that is prone to protocol layer attack. DRDoS (distributed and reflective denial of service attack) mainly concentrates on exhausting the resources of the target server based on deploying continuous requests to the server and spoofing the IP address of the remote server. In the context of DRDoS attacks, two factors play a vital role in detecting the impact of the attack such that initially, attackers will try to amplify the network bandwidth by misusing the network protocol on generating unnecessary traffic. As the IP address spoofing mechanism is constrained to TCP handshake policy review of different TCP protocols has been excluded. It is observed from the research studies that the following protocols shown in table 6 are prone to DRDoS attacks.

Table 6. Protocols that are more prone to the DRDoS attacks

| Protocol | Description |
|----------|-------------|
| NTP      | This protocol mainly related to the time synchronization with 123 ports |
| NetBios  | It acts as a Name Service Protocol for API that represents NetBios |
| DNS      | Domain name resolution protocol with 53 ports |
| SSDP     | UPhP- enabled hosts are discovered using this protocol with 1900 ports |
| SNMP2    | It usually monitors the devices that are attached to the network with around 161 ports |
| Sality   | It is considered as malware dropper protocol that works on P2P mechanism |
| ZAv2     | It enables rootkit for P2P based computing |

Aangnostopoulos et al [19] in his research study have developed a mechanism that amplifies DNS and demonstrated the scenario of the real attack. The demonstration of the work include two groups of packets that includes 3539 packets with the size around 5MB and 3110 packets with size around 3.5 MB that are recorded on the target server with the range of amplification in between 37 to 44 such that the individual attacking node will have the capability of releasing 3 to 4 Mbps of unnecessary traffic to victim. Further, the research
work in [20] utilizes DNS query in the context of analyzing DNS based DDoS attack amplification that eventually targets the remote server. Kumbourakis et.al in his article [21] have devised a mechanism that operates on individual-centric mapping phenomenon that mainly works on the request-response scenario of the DNS query wherein the context of the DNS amplification there be an absence of such kind of querying procedure. Weizhang et.al [22] in the context of detecting the anomaly has made use of the data mining based approaches that classify the traffic of the DNS query. UzmaSattar et.al [23] have developed a modified bloom filter based mechanism such that his research study that demonstrates the process in which the filter stores the request generated to the server such that if the response from the server is delivered in specific time period then it allows that particular IP address else the IP address is blocked. Further, the studies in [24] addressed the context of the trivial file transfer protocol through which the amplification factor is elevated. Prediction and monitoring of the DNS traffic caused by the botnet will gradually increase as synthesized in the literature[25][26]. Addressing the usage of the artificial neural network in the context of detecting and predicting on classifying normal data packet and DDoS attack intruder packets within the realtime environments on blocking the forged data packets before these packets arrive the target server. TejmaniSinam et.al [27] in the context of detecting VOIP over the network have devised adamachine learning technique. In this research study, the main objective is to classify the application traffics of VOIP based on the usage of the application The role of the proposed machine learning algorithm is to classify the VOIP traffic from forged data packets.

4.3 Detection and prediction of Protocol attacks using Machine learning Mechanisms

A research study conducted in [28] addressing the context of smurf attack in which a large number of ICMP data packets are transported towards the target remote server in such a way that it is flooded over with ping messages that include five different steps in the process of executing the smurf attack without any inconsistencies. The most common effect of a smurf attack is that it will cripple the target server with unlimited ping such that it may cause huge revenue loss. In a few cases, certain smurf attacks are launched along with rockets that allow accessing the system to shutdown the server. Further in [29], the research study focus on the context of designing a packet marking algorithm that was based on the ICMP trackback phenomenon to predict a DDoS attack. In this scenario, the work is evaluated based on two different mechanisms in the initial context a virtual machine is utilized to trackback the system further in the next step the algorithm evaluates the data packets launched by the attacker. Data transmission is initially established between the client and server using TCP handshake protocol and usually, this phenomenon is known as three-way handshake mechanism of TCP where the client and the server are initially communicated with the message as a SYN message and acknowledgment as SYN-ACK to establish the connection. In this scenario, if the attacker floods SYN messages continuously to the server irrespective of the ACK then it is called a TCP-SYN flooding attack. This attack is usually launched by spoofing the IP address[30].

The research studies in [31] indicate that the size of the IP packets as 65535 bytes that includes the size of the headers. The server will not be able to handle the requested ping packet that is larger than the indicated maximum size that breaches the IP regulations. In general, the attackers will flood the forged data packets in the form of fragments to the servers that are reassembled by the target servers if an oversized packet fragment occurs it is prone to be a ping of death packet that crashes the target server.

**Figure 3 Quantitative analysis of publications related to Different types of DDoS attacks**

V. ANALYSIS AND QUALITY ASSESSMENT OF THE REVIEW

The systematic literature review presented in this article made an attempt to identify the role of machine learning and deep learning approaches in the context of detection and prediction of DDoS attacks that could be executed in various distributed computing environments and software-defined networking environments. The quality assessment of the review is conducted based on mapping the research questions (RQ’s) framed in section 2.1. Initially, the fundamentals of DDoS attacks are detailed in section 3 that will map to RQ1. The detailed review of the existing techniques that specify RQ2 is demonstrated in section 4. Figure 3 demonstrates various existing techniques that briefly explain the range of publications over the years addressing different types of DDoS attacks. Table 7 provides the synthesis of various popular works along with their implementation details.
Prediction of DDoS Attacks using Machine Learning and Deep Learning Algorithms

5.1 Research Gap

VI. CONCLUSION

This article includes the systematic study of literature in the context of detecting and predicting DDoS attacks on utilizing machine learning and deep learning algorithms. In this study, after the thorough filtering process, 34 articles are considered for the study through which it is observed that most of the existing research includes solutions and algorithmic patterns that are framed based on the statistical algorithms such that most this algorithms suffer from computational complexity. Additionally, there are very few publications addressing the scope of predicting the DDoS. This study outlines the synthesis of various DDoS attacks and their countermeasure algorithms that enables the researchers of the next generation to easily identify the research gap in the context of applying machine learning algorithms to automate the process of predicting DDoS attacks in various distributed networks.
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