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RECTIFIED PROBABILISTIC PACKET MARKING BASED ON TRACE BACK MECHANISM

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Abstract: The denial-of-service (DoS) attack has been a pressing problem in recent years. DoS defiance research has blossomed into one of the main streams in network security. Various techniques such as the pushback message, ICMP trace back, and the packet filtering techniques are the results from this active field of research. The probabilistic packet marking (PPM) algorithm attracted the most attention in contributing the idea of IP trace back. The most interesting point of this IP trace back approach is that it allows routers to encode certain information on the attack packets based on a predetermined probability. Upon receiving a sufficient number of marked packets, the victim (or a data collection node) can construct the set of paths that the attack packets traversed and, hence, the victim can obtain the locations of the attackers.

Keywords: Packet Filtering; Traffic Control; IP Trace back; DDoS Attack, Deterministic Flow Marking.

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1. INTRODUCTION

The world has seen rapid advances in science and technology in the last two decades, which has enabled dealing with a wide spectrum of human needs effectively. These needs vary from simple day-to-day needs like paying electricity bills, booking train tickets, etc., to sophisticated needs like power grids for power generation and sharing. These technologies have taken human life into much higher levels of sophistication and ease. But in the middle of this phenomenon, the rise and growth of a parallel technology is startling – that of compromising security, thereby resulting in different effects detrimental to the use of technology. This includes attacks on information, such as stealing of private information, hacking, and outage of services. Media and other forms of network security literature report the possibility of the existence of underground anonymous attack networks which can effectively attack any given tar-get at any time. This only shows a possible shift in attack perspective in current days and in times to come – from wars causing physical damage and destruction to what is termed "information warfare", compromising of attacks mentioned above. The twist in the latter is that these attacks are mostly performed by attackers/networks who can conceal themselves.

While the range of attacks that can be performed on targets is as broad as the spectrum of constructive technology itself, this thesis deals with a particular class of attacks known as Denial of Service (DoS) attacks. Denial of Service (DoS) attacks are a class of attacks on targets, which aims at exhausting target resources, thereby denying service to valid users. The target resources could be in terms of space and/or time. For example, servers providing SSL service could be time-attacked by making them perform a lot of expensive cryptographic operations (public key decryption in this case) thereby preventing them from serving their genuine clients. Alternately, servers could also be space-attacked by exhausting their bandwidth or connection buffers with lot of bogus packets/requests.

In recent years much interest and consideration has been paid to the topic of securing the Internet infrastructure that continues to become a medium for a broad range of transactions. Currently, Internet security attracts much attention from the industry, academia and even United States (US) congress which held a number of congressional hearings on the subject [1, 2]. A number of approaches to security have been proposed, each attempting to mitigate a specific set of concerns. The specific threat, which is the main focus of this work, is anonymous attacks. In anonymous attacks, the identity of the attacker(s) is not immediately available to the victim since the Source Address (SA) field in the attack packets is spoofed. (Distributed) Denial of Service ((D)DoS) attacks are anonymous attacks, which are currently attract the most attention, since there is no obvious way to prevent them or to trace them. The anatomy of

DDoS attacks is described by S. Gibson in [3], and his own experiences of being a victim of one, in [4].

Currently, there are several ways of dealing with anonymous attacks. They include source address filtering, SYN Flood Protection, and implementing a BlackHole Router server. Source address filtering, introduced by P. Ferguson [5], prevents packets with the values of the SA field outside preset appropriate range from entering the Internet. If deployed on every ingress interface, this would drastically reduce the number of anonymous packets in the Internet. Unfortunately, source address filtering is associated with high overhead and administrative burden as noted by S. Savage, et al. [6] and is not widely deployed. SYN Flood protection monitors half-open TCP connection and does not allow more than a certain number of them to exist simultaneously. SYN Flood protection prevents only SYN Flood type (D)DoS attacks and is useless against other types of anonymous attacks. Finally, the ISPs can determine the interface, where the packets of DoS attack entered its network, if the customer reports the attack, by Black Holing a router on its network as described by UUNET engineers [7]. This method involves human interaction, works only for the backscatter attacks, discussed by D. Moore, G. Voelker, and S. Savage [8], must be performed while the attack is still in progress, and is limited to the boundaries of the given ISP.

As the Internet becomes an integral part in many people's lives, the need to keep servers protected, online, and available has become increasingly important. In recent years, denial-of-service (DoS) attacks and distributed DoS (DDoS) attacks have become more sophisticated and effective at obstructing this availability. In 2000, several online companies such as eBay, Amazon.com, CNN.com, and Yahoo were all affected by a large scale DDoS attack [1]. During this attack, their websites were rendered virtually unreachable to many Internet users, resulting in severe financial losses, in addition to the many unsatisfied customers. In 2002, several root Domain Name System (DNS) servers were brought down by yet another DDoS attack [2]. This attack demonstrated that attackers were becoming more intelligent because critical systems were now being attacked. The general trend in DoS attacks implies that future attacks are likely to become much worse and more disruptive, affecting a larger number of Internet users. In addition to these highly publicized attacks, there have been countless other smaller scale DoS attacks that have targeted various companies or corporations. Regardless of their scale, DoS attacks have become a serious threat and nuisance throughout the Internet because they can directly be used to destabilize the Internet. Despite the knowledge of their existence, an effective defense solution that is both practical to implement and easy to deploy has yet to be developed. This thesis presents a discussion about the current research in this

area and presents two different novel mitigation techniques that minimize the crippling effects of a network-based DoS attack.

1.1 Denial-of-Service Attacks

This dissertation studies denial of service (DoS) attacks in computer networks. The goal of these attacks is to prevent availability of network services from their legitimate users. This dissertation presents a structured view on possible attack and defense mechanisms, describes some new defense mechanisms, and provides new information on selecting and evaluating defense mechanisms. Defending against DoS attacks is network and computer security. As scientific disciplines, network and computer security are relatively new. An indication of this is that even computer security terminology has not yet stabilized [12, 28]. Computer and network security were first studied in the early 1970s, and some of these earliest security papers are listed and available in [26].

There are many different types of DoS attacks and the number of them only increases with the release of newer protocols and network applications. In order to gain a better understanding of the most common DoS attacks, it is best to separate these attacks into two different categories: local and remote (or network based). These attacks can be further separated into two more subcategories that describe the overall goal of the attack: stopping critical services and exhausting system resources [3].

A local DoS attack is typically a form of malicious software that resides on the local machine that intends to disrupt the normal operation of the computer's programs, processes, or services. These attacks have the ability to stop these processes from executing and cause problems for the current user and possibly other remote users that are depending upon that computer's service. Besides stopping critical processes on a local computer, local DoS attacks can also exhaust system resources such as memory, clock cycles, disk space, and even network resources. Exhausting resources on a local system is an effective means to conduct a DoS attack because when the required system resources are not available on the local machine, new applications or data can neither be executed nor processed. In this case the attack causes more damage because it does not target a specific application or weakness; it prohibits or limits the capabilities of that system and prevents users from further and continued use of that machine. Examples of these resource exhaustion attacks are a fork bomb or an application that intentionally causes errors to fill up an error log, thus exhausting disk space [3].

Remote DoS attacks, or network-based DoS attacks, is an attack where the attacker attempts to deny, disrupt, or degrade a client's access to a network service by any means necessary via a

remote computer. Network-based DoS attacks can both stop current processes and exhaust system resources. Thus, when an attack is underway, the end host or server will be virtually unavailable to other clients. Examples of a remote attack that stops services are the Land attack and the Teardrop attack [3]. Examples of network-based resource-exhaustion attacks are synflood attacks, Smurf attacks, and Distributed DoS flooding attacks [3]. With the increased usage of the Internet and broadband

Internet access, network-based resource-exhaustion attacks are becoming more common and popular because they are among the easiest to launch and one of the most effective forms of a DoS attack. Unfortunately, these attacks are becoming the most difficult to defend against.

2. RELATED WORK

Providing networks with countermeasures against Denial of Service (DoS) attacks has become a pressing security issue in the Internet today. Network services get disrupted or become totally unavailable as malicious attackers flood a victim network with large amount of useless traffic. For accountability purpose and to thwart those attacks, it is essential to identify the source of these attacks, which is usually concealed using faked or spoofed IP addresses, and is known as the IP Traceback problem.

Packet marking is a traceback approach that calls for routers to mark packets along the attack path with self-identifying information. In Probabilistic Packet Marking (PPM) routers probabilistically decide whether or not to mark packets. A victim node relies on the amount of marked packet samples received to reconstruct the attack path. However, a fixed marking probability set for all routers in PPM has proved to be ineffective as marked packets from distant routers are more likely to be remarked by downstream routers. This entails a loss of information and leads to increase in the volume of packets needed to reconstruct the attack path. Enabling each router to adjust its marking probability so as to obtain equal samples of marked packets, in particular from the furthest routers would help in minimizing the time taken to reconstruct the attack path.

Dynamic schemes have been proposed for adjusting the marking probability, which can be derived by accurately estimating a router's position in the attack path. However, most schemes are highly dependent on the underlying protocols and require routers to have knowledge of distance information to the potential victim node. This adversely increases the router overhead and is time consuming for real-time packet marking scenarios.

In this work we propose an algorithm that dynamically set the value of the marking probability based on the 8-bit Time-To-Live (TTL) field in the IP header, which is a value that can be directly accessed by routers without external support. Our proposed scheme utilizes the variable TTL value as an estimate of the distance traveled by a packet and thereby its position in the attack path to derive the marking probability value. Our algorithm was simulated with a number of test cases using a user-friendly simulator that was developed to that effect. Results in terms of false positives, reconstruction time and number of packets needed for reconstruction have shown the efficacy of our dynamic scheme, which offers significantly higher precision with fewer overheads both at the router and at the victim in reconstructing the attack path. The main advantages of the proposed scheme reside both in its simplicity and low router overhead while offering comparable results with other dynamic schemes and outperforming static schemes at large attack distances.

Future work includes fine-tuning the derivation of the dynamic marking probability to further improve performance at larger attack distances and a study of its applicability and performance in IPv6 networks.

2.1 Probabilistic Packet Marking (PPM)

The current approaches are liable to either increasing the network overhead, processing done at the routers or processing done at the victim node. One of the approaches that have garnered a lot of attention recently is the probabilistic packet marking (PPM) approach. In this paper introduce an extension of this probabilistic packet marking scheme that significantly reduces the number of packets required to reconstruct the attacking path

2.1.1 DoS attacks

Effective mitigation of denial of service (DoS) attack is a pressing problem on the Internet. In many instances, DoS attacks can be prevented if the spoofed source IP address is traced back to its origin which allows assigning penalties to the offending party or isolating the compromised hosts and domains from the rest of the network. IP traceback mechanisms based on probabilistic packet marking (PPM) have been proposed for achieving traceback of DoS attacks.

Kihong Park *et al*. [1] have proposed that probabilistic packet marking-of interest due to its efficiency and implementability vis-a-vis deterministic packet marking and logging or messaging based schemes-suffers under spoofing of the marking field in the IP header by the attacker which could impede traceback by the victim. We show that there was a trade-off between the ability of the victim to localize the attacker and the severity of the DoS attack, which was

represented as a function of the marking probability, path length, and traffic volume. The optimal decision problem-the victim can choose the marking probability whereas the attacker could choose the spoofed marking value, source address, and attack volume-could be expressed as a constrained minimax optimization problem, where the victim chooses the marking probability such that the number of forgeable attack paths was minimized. We show that the attacker's ability to hide his location is curtailed by increasing the marking probability, however, the latter is upper-bounded due to sampling constraints. In typical IP internets, the attacker's address could be localized to within 2-5 equally likely sites which renders PPM effective against single source attacks. Under distributed DoS attacks, the uncertainty achievable by the attacker could be amplified, which diminishes the effectiveness of PPM

3. THE PROPOSED DEFENSE SYSTEM

One of the major open problems in network security today is Distributed Denial of Service (DDoS) Attacks. In a DDoS attack, the attacker sends vast amounts of traffic from a large number of systems that are controlled by him/her to a victim network or system. The result is that the victim's resources become overloaded and it cannot process the requests of legitimate users, thus any services that this system provides become unusable. One of the main difficulties in the detection, and prevention of DDoS attacks is that the incoming packets cannot be traced back to the source of the attack, because (typically) they contain invalid or spoofed source IP address. For that reason, a victim system cannot determine whether an incoming packet is part of a DDoS attack or belongs to a legitimate user. DDoS attack is a major source of Cyber-attack [1]. The attacker tries to hide its identification by spoofing the IP Address. Current IP traceback mechanisms can be mainly classified into four categories [2]. These are packet marking, Debugging, Link Testing and Messaging. Packet marking mechanisms mark the identification of the routers in the IP packets. Marking mechanism such as Probabilistic Packet Marking Mechanism (PPM) and Deterministic Packet Marking (DPM) mechanism rely on packet marking for identification of attackers. In PPM, all routers mark the packet using some probability. The victim reconstructs the path back to the source using the bit encoding by each routers. PPM mechanism can also uses TTL value in the packet to identify the source of malicious packets. DPM marks the packet with fixed probability. It uses the identification of ingress routers while marking the packets. SIT (Speedy IP traceback).uses MAC address for marking in the IP packet [3]. This is based on the assumption that the MAC address may not be spoofed by the user since it changes from one hop to other. So, MAC address of source is marked in the packet which can later easily traced. But, MAC address copying is violation of privacy. It is also subject to spoofing.

One marking mechanism uses checksum to encode the IP Address and Traffic filtering mechanism at ingress router to drop the spoof packets at ingress interface [4].

Link testing methods include input debugging [5] and controlled flooding methods [6]. The main idea is to start from the victim to locate the attacker from upstream links by testing the possible routes and then finding the attack path. This technique has limitations when there are branching in the network as it increases the overloading of the network. When the Network Traffic is quite heavy, this technique is not

Feasible to use. If the victim is receiving significant attack traffic, then this technique is less effective.

Another traceback technique is Messaging. Bellovin [7] proposed ICMP messages to traceback the source of attacker. ICMP messages are sent to find the source of forged packets. But, the limitation of this technique is that generally routers do not allow to exchange of ICMP messages. Also, when the network traffic is very high, this generates additional traffic.

3.1.1 Basic assumptions

The assumptions that will be used in this paper are largely borrowed from [7] and are the following:

- The attacker may generate any packet
- The attacker knows that he is being traced
- The attacker knows the traceback scheme
- Routing is stable most of the time
- Routers are not compromised
- Routers are both CPU and memory limited

The first three assumptions mean that the proposed marking scheme cannot contain any weaknesses that could be exploited by the attacker. The attacker can craft any kind of packet, even packets that bear such markings that could circumvent traceback or filtering of his/her packets. The fourth assumption dictates that we expect most of the packets from a specific source that have the same destination, to follow the same path. Efficiency of this marking scheme can be degraded if the assumption is not true, but success of the scheme is not compromised. The fifth assumption has already been thoroughly discussed in [7] [9] and the

last assumption dictates that the overhead that this marking scheme poses to the routers should be limited.

3.1.2 Purpose of Marking Scheme

The basic notion of this marking scheme is that in order to stop an ongoing DDoS attack; we primarily need the information that enables us to distinguish the packets that belong to the attack from the packets that belong to normal users of the service. The source IP address of the packet is not reliable during a DDoS attack, as discussed in section 1.

What is of most importance in the procedure of preventing an ongoing DDoS attack is that we need this information to be part of the packet itself. This information must be reliable and enable us to identify the true source of the packet as accurately as possible. Thus a victim of a DDoS attack can use this information together with a DDoS detection system in order to correctly identify and filter in real time the attack traffic. After the end of the DDoS attack, we would like to be able to trace the sources of the attack. We need to be able to use the gathered information in order to trace as accurately as possible the source of the packets that have been classified as part of the DDoS attack.

Most existing packet-marking schemes need more than one packet to determine the source of an incoming packet and the traceback procedure is often computational prohibiting to be done for each packet in real time. Other traceback schemes rely on the fact that traceback of a packet is an infrequent procedure. This marking scheme provides the means to filter DDoS attack traffic in real time and to trace the sources of the attack in a post-mortem fashion. The compromise that has to be done is that due to the limited available space for the traceback information (see section 5.3) and the fact that exact host tracing is very difficult on the IP level; this marking scheme as well as similar traceback schemes, can trace the source of the packet up to the closest router. Another compromise is that there will be some false positives, meaning that some packets will be falsely considered part of the attack traffic. However “An ideal traceback system produces no false negatives while attempting to minimize false positives” [9].

CONCLUSION

In this work, have implemented and evaluated the proposed system most interesting point of this IP trace back approach is that it allows routers to encode certain information on the attack packets based on a predetermined probability. Upon receiving a sufficient number of marked packets, the victim (or a data collection node) can construct the set of paths that the attack packets traversed and, hence, the victim can obtain the locations of the attackers.

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