Unit V

Information gathering, also known as reconnaissance, is an essential phase in network security. It involves collecting information about a target system or network to gain insights into its infrastructure, vulnerabilities, and potential attack vectors. The goal of information gathering is to gather intelligence that can be used to identify security weaknesses and plan further steps in a targeted attack or vulnerability assessment. Here are some common methods and techniques used in information gathering:

1. Passive Information Gathering: This involves collecting publicly available information about the target network without directly interacting with it. It includes techniques like:

   Open-source intelligence (OSINT): Gathering information from publicly available sources like websites, search engines, social media, online forums, and public databases.

   WHOIS lookup: Retrieving registration details of domain names, including the owner's contact information, domain expiration date, and associated IP addresses. DNS enumeration: Gathering information about DNS records, such as hostnames, IP addresses, mail servers, and subdomains.

   Network mapping: Using tools like Nmap to identify active hosts, open ports, and network topology.

2. Active Information Gathering: This involves direct interaction with the target network to gather more specific information. It includes techniques like:

Port scanning: Using tools like Nmap to scan for open ports, identify services running on those ports, and gather banners and version information. Service enumeration: Gathering information about specific services and their configurations, such as identifying running software versions and checking for default or weak credentials.

Vulnerability scanning: Using tools like Nessus or OpenVAS to scan for known vulnerabilities in target systems and applications.

Social engineering: Gathering information by exploiting human vulnerabilities, such as phishing, pretexting, or impersonation techniques.

3. Active Reconnaissance: This involves actively probing the target network to gather more detailed information about its infrastructure and security posture. Techniques used in active reconnaissance include:

Network sniffing: Capturing and analyzing network traffic to gather information about devices, protocols, and potential vulnerabilities.

Packet crafting: Creating and sending custom packets to elicit responses from the target network, helping to identify filtering rules, firewall configurations, and potential security gaps.

Wireless network scanning: Identifying wireless networks in the vicinity, including their SSIDs, encryption types, and potential vulnerabilities.

Social engineering: Interacting with employees or individuals associated with the target network to gather sensitive information or exploit human trust.

It's important to note that information gathering should be performed ethically and legally, with proper authorization and in adherence to applicable laws and regulations. Unauthorized and malicious information gathering can lead to legal consequences.

Traceroute

Traceroute, also known as tracert in some operating systems, is a network diagnostic tool used to trace the path that packets take from a source device to a destination device over an IP network. It helps to identify the intermediate routers or hops that the packets traverse, measure the round-trip time (RTT) between each hop, and identify potential network bottlenecks or issues.

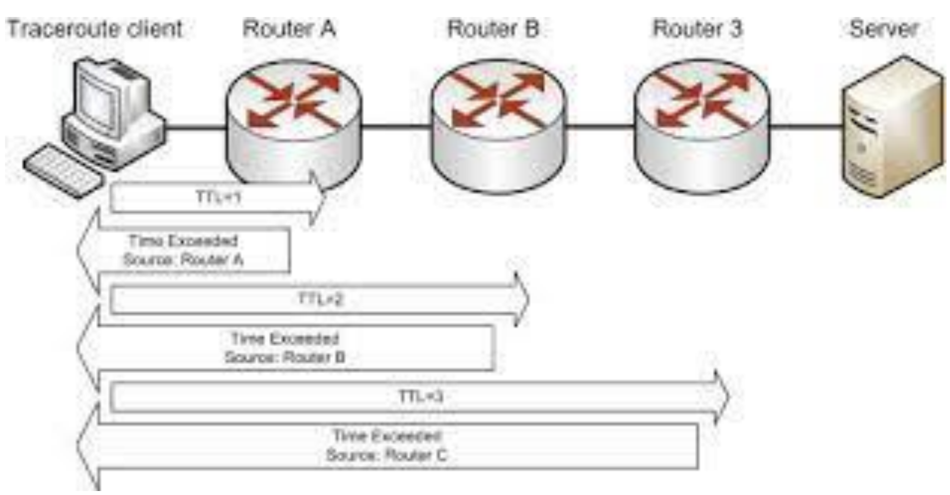
Here's how traceroute works:

1. A traceroute command is executed from the source device to the destination device's IP address or hostname.

2. The source device sends out a series of ICMP (Internet Control Message Protocol) Echo Request packets with incrementing TTL (Time to Live) values.

3. The TTL field specifies the maximum number of hops (routers) that a packet can traverse before it is discarded. The initial TTL value is typically set to 1.

4. When the first router receives the packet, it decrements the TTL value by 1. If the TTL becomes 0, the router discards the packet and sends an ICMP Time Exceeded message back to the source device.



5. The ICMP Time Exceeded message contains information about the router that discarded the packet. This information includes the router's IP address and sometimes its hostname.

6. The source device records the IP address and RTT of the first hop and sends another packet with a TTL value of 2.

7. The process continues, incrementing the TTL value with each iteration until the packet reaches the destination device or a maximum hop limit is reached.

8. Each intermediate router along the path repeats the process of decrementing the TTL, discarding the packet, and sending an ICMP Time Exceeded message back to the source device.

9. When the destination device receives the packet, it responds with an ICMP Echo Reply message.

10. The source device records the IP address and RTT of the final hop and displays the collected information in the traceroute output.

The traceroute output typically includes a list of the intermediate routers (hops) along with their IP addresses, RTT values, and sometimes their hostnames. This information can help identify network latency, packet loss, or routing issues along the path between the source and destination devices.

Traceroute is a valuable tool for network troubleshooting, diagnosing network performance problems, and identifying potential network bottlenecks. However, it's important to note that some routers or firewalls may be configured to block ICMP packets, which can affect the accuracy of traceroute results.

Ping sweeping

Ping sweeping, also known as ICMP sweeping, is a network scanning technique used in network security to identify live hosts within a given IP range. It involves sending ICMP Echo Request (ping) packets to multiple IP addresses and analyzing the responses to determine which hosts are reachable.

Here's how ping sweeping works:

1. A ping sweep is initiated by selecting a range of IP addresses to scan. This can be a specific subnet or a range of IP addresses.

2. Starting from the first IP address in the range, ICMP Echo Request packets (ping) are sent to each IP address sequentially.

3. If a host is live and reachable, it will respond to the ICMP Echo Request with an ICMP Echo Reply packet.

4. The scanning tool or script that initiates the ping sweep listens for ICMP Echo Reply packets and records the IP addresses that respond.

5. The process continues until all IP addresses in the specified range have been scanned or a timeout limit is reached for non-responsive hosts.

The results of a ping sweep provide information about live hosts within the scanned IP range. This can be useful for network administrators and security professionals to identify active devices on a network, detect unauthorized devices, or validate the reachability of specific hosts.

It's important to note that while ping sweeping is a relatively simple and common network scanning technique, it may not always provide accurate results. Some hosts or firewalls may be configured to block ICMP Echo Request packets or prioritize ICMP traffic differently, which can affect the success rate of ping sweep scans. Additionally, ping sweeping alone does not provide detailed information about the services or vulnerabilities present on the identified hosts. Therefore, it is often used as an initial step in a broader network reconnaissance process.

Port Scanning

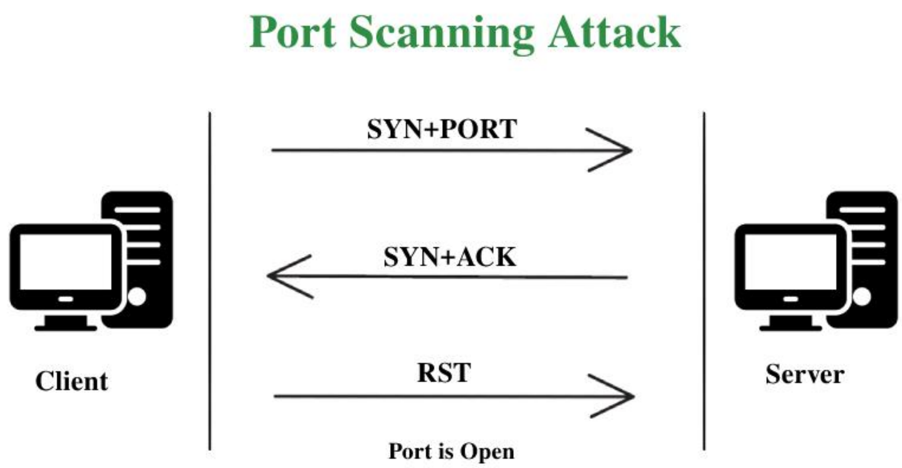
Port scanning is a network scanning technique used in network security to identify open ports on a target system or network. It involves systematically scanning a range of ports on a target host to determine which ports are listening and accepting connections. Port scanning is commonly used to assess the security posture of a network, identify potential vulnerabilities, and gather information about running services.

Here's how port scanning works:

1. Port scanning begins by selecting a target host or range of IP addresses to scan. The target can be a specific system, a subnet, or an entire network.

2. Various scanning techniques and tools are used to send network packets to the target host's IP addresses and specific ports.

3. The scanning tool sends different types of packets, such as TCP SYN, UDP, or ICMP, to specific port numbers.



4. The target host responds differently depending on the port's state:

- If a port is open and accepting connections, it may respond with an acknowledgment (ACK) packet or a specific response indicating the service running on that port.

- If a port is closed and not accepting connections, the target host may respond with a TCP RST (reset) packet or an ICMP Port Unreachable message.

- If a port is filtered or blocked by a firewall, the scanning tool may receive no response or the target host may respond with ICMP Destination Unreachable messages.

5. The scanning tool analyzes the responses received for each port to determine their state (open, closed, filtered), records the results, and generates a report.

Different types of port scanning techniques are commonly used, including:

- TCP Connect Scanning: This technique establishes a full TCP connection with the target host to determine if a port is open. It completes the three-way handshake (SYN, SYN-ACK, ACK) and examines the responses.

- SYN Scanning (also known as Half-Open Scanning): This technique sends SYN packets to the target ports and analyzes the response. It does not complete the handshake, saving time and resources. If a SYN-ACK response is received, the port is considered open.
- UDP Scanning: UDP ports are scanned by sending UDP packets and analyzing the responses. Since UDP is connectionless, determining the state of UDP ports can be more challenging than TCP ports.
- FIN, Xmas, and NULL Scanning: These scanning techniques exploit certain TCP packet flag combinations to identify open ports. They send packets with specific flag combinations and analyze the target's response to determine the port state.

Port scanning is a critical part of network security assessments and vulnerability testing. However, it's important to note that indiscriminate or unauthorized port scanning can be seen as malicious activity and may violate laws and regulations. Therefore, it's crucial to obtain proper authorization and adhere to applicable legal and ethical guidelines when conducting port scanning activities.

ICMP scanning

ICMP scanning is a network scanning technique that focuses on using ICMP (Internet Control Message Protocol) packets to gather information about hosts on a network. ICMP scanning is primarily used to identify live hosts and gather network topology information, rather than specifically targeting open ports or services like other scanning techniques.

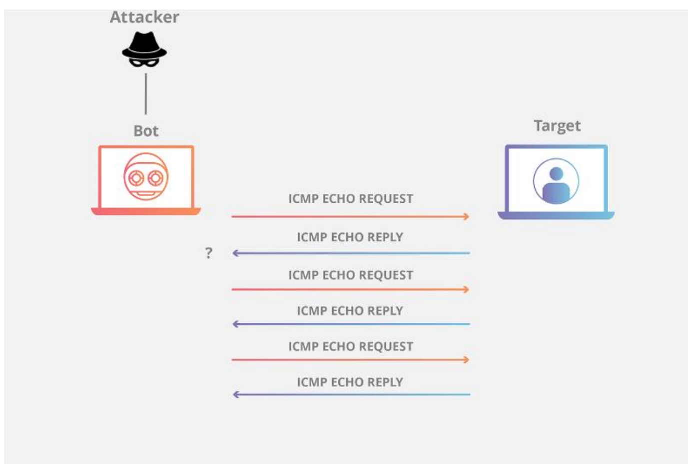
Here's how ICMP scanning works:

1. ICMP scanning involves sending ICMP Echo Request (ping) packets to target hosts or IP addresses within a specified range.

2. The scanning tool sends ICMP Echo Request packets to each IP address sequentially.

3. If a host is live and reachable, it will respond to the ICMP Echo Request with an ICMP Echo Reply packet.

4. The scanning tool listens for ICMP Echo Reply packets and records the IP addresses that respond, indicating live hosts.



5. The results of an ICMP scan provide information about the live hosts within the scanned IP range, helping to identify active devices on a network and determine network reachability.

ICMP scanning can be useful for basic network reconnaissance, such as identifying active hosts, detecting network connectivity issues, or mapping network topology. However, it's important to note that ICMP scanning has limitations:

- Some hosts or firewalls may be configured to block ICMP Echo Request packets, limiting the effectiveness of ICMP scanning.

- ICMP scanning does not provide detailed information about open ports or running services on the identified hosts.
- ICMP replies can be generated by routers or firewalls, which can make it challenging to accurately determine the actual hosts behind those IP addresses.

Therefore, ICMP scanning is typically used as a complementary technique alongside other scanning methods, such as port scanning or service enumeration, to obtain a more comprehensive understanding of the target network. Additionally, it's important to conduct ICMP scanning activities ethically and with proper authorization to avoid any legal or policy violations.

1. Introduction

It was in early 2000, that most people became aware of the dangers of distributed denial of service (DDoS) attacks when a series of them knocked such popular Web sites as Yahoo, CNN and Amazon off the air. More recently, a pair of DDoS attacks nailed The SCO Group's Web site and many people thought that it was a hoax because surely any company today could stop a simple DDoS SYN attack. Wrong.

It has been almost five years now, but DDoS attacks are still difficult to block. Indeed, some DDoS attacks, including SYN, if they are made with enough resources are impossible to stop.

No server, no matter how well it is protected, can be expected to stand up to an attack made by thousands of machines. Indeed, Arbor Networks, a leading anti-DDoS company, reports DDoS zombie (host previously compromised by the attacker, which effectively accomplish the DoS attack) armies of up to 50,000 systems. Fortunately, major DDoS attacks are difficult to make. Unfortunately, minor DDoS attacks are easy to make.

In part, that is because there are so many kinds of DDoS attacks. It may do it by attacking the TCP/IP protocol, it may do it by assaulting server resources, or it could be as simple as too many users demanding too much bandwidth at one time.

Unfortunately, as more and more users add broadband connections without the least idea of how to handle Internet security, these kinds of attacks will only become more common. With this document it is our intention to present how denial of service attacks can occur.

In section 2 of this report data security concepts and a TCP/IP overview are presented. Section 3 describes DoS and DDoS attacks through a presentation of the major attacks of this kind. Section 4 highlights some trend lines that permit to avoid DDoS attacks, or at least to limit their effects in the network being attacked. Finally, section 5 is a conclusion of all this study.

2. A Brief Background

This section is intended to overview some of the main aspects when talking about security and attacks. This includes a broad classification for the attacks, based on how they affect data, and some main protocols of the TCP/IP suite against which the attacks presented are perpetrated or that are used to perpetrate an attack.

2.1. Data Security

Most of the literature about security concepts split the data security into three different parts: integrity, confidentiality and availability.

Integrity is related with the trust that we have about data. So, if someone who is not allowed to manage or to change data is doing that, the integrity is compromised. You can no more trust that your valuable information is true any more.

The information's confidentiality is compromised if a person is able to enter a computer(s) that he is not allowed to. He/she may then get to know information not intended to be available for that person. He/she may even distribute the information.

That latter category - availability - is the one where the attacks discussed in this paper belong. The data's availability is of course important in running a business and huge losses may occur if important information is no longer available as a result of an attack against the computers. Such attacks are often named "Denial-of-Service" (DOS).

2.2. About the TCP/IP protocol

The attacks which are discussed in this paper are all utilizing weaknesses in the implementation of the TCP/IP protocols to make the attacked computer or network stop working as intended. To understand the attacks one has to have a basic knowledge of how these protocols are intended to function.

TCP/IP is the acronym of Transmission Control Protocol/Internet Protocol and is one of several network protocols developed by the United States Department of Defense (DoD) at the end of the 1970s. The reason why such a protocol was designed was the need to build a network of computers being able to connect to other networks of the same kind (routing). This network was named ARPANET (Advanced Research Project Agency Internetwork), and is the predecessor of what we call Internet these days.

TCP/IP is a protocol suite which is used to transfer data through networks. Actually TCP/IP consists of several protocols. The most important are:

- **IP Internet Protocol**
  This protocol mainly takes care of specifying where to send the data. To do that, each IP packet has sender and receiver information [1]. The most common DoS attacks at the IP level exploit the IP packet format.

- **TCP Transmission Control Protocol**
  This protocol handles the secure delivery of data to the address specified in the IP protocol [2].

  Most of the TCP level attacks exploit weaknesses present in the implementations of the TCP finite state machine. By attacking specific weaknesses in applications and implementations of TCP, it is possible for an attacker to make services or systems crash, refuse service, or otherwise become unstable.

- **UDP User Datagram Protocol**
  UDP may be used as an alternative to TCP. The difference is that UDP does not guarantee that data reaches the receiver, since it is connectionless and a protocol

without any packet loss recovery mechanism [3]. On the other hand this protocol has less overhead than the TCP protocol – data transmission is faster. UDP packets are mainly used to perpetrate flooding attacks.

- **ICMP Internet Control Message Protocol**
  ICMP is a subset of the TCP/IP suite of protocols that transmits error and control messages about the network situation between systems [4]. Two specific instances of the ICMP are the ICMP ECHO_REQUEST and ICMP ECHO_RESPONSE datagrams. These two instances can be used by a local host to determine whether a remote system is reachable via the network; this is commonly achieved using the "ping" command. Under certain conditions, flooding ICMP packets might denial services.

A communication through a network using TCP/IP or UDP/IP will typically use several packets. Each of the packets will have a sending and a receiving address, some data and some additional control information. Particularly, the address information is part of the IP protocol – being the other data in the TCP or the UDP part of the packet. ICMP has no separate TCP part – all the necessary information is in the ICMP packet.

In addition to the recipient's address all TCP/IP and UDP/IP communication uses a special port number which it connects to. These port numbers determine the kind of service the sender wants to communicate to the receiver of information.

3. DoS Attacks

DoS attacks today are part of every Internet user's life. They are happening all the time, and all the Internet users, as a community, have some part in creating them, suffering from them or even loosing time and money because of them. DoS attacks do not have anything to do with breaking into computers, taking control over remote hosts on the Internet or stealing privileged information like credit card numbers. Using the Internet way of speaking DoS is neither a Hack nor a Crack. It is a whole new and different subject.

This section is entirely devoted to denial of service attacks and its variants. Here, we present a broad definition of this kind of network threat, and examples of the most common attacks.

3.1. Definitions

The sole purpose of DoS attacks is to disrupt the services offered by the victim. While the attack is in place, and no action has been taken to fix the problem, the victim would not be able to provide its services on the Internet. DoS attacks are really a form of vandalism against Internet services. DoS attacks take advantage of weaknesses in the IP protocol stack in order to disrupt Internet services.

DoS attacks can take several forms and can be categorized according to several parameters. Particularly, in this study we differentiate denial of service attacks based on where is the origin of the attack being generated at.

“Normal” DoS attacks are being generated by a single host (or small number of hosts at the same location). The only real way for DoS attacks to impose a real threat is to exploit some software or design flaw. Such flaws can include, for example, wrong implementations of the IP stack, which crash the whole host when receiving a non-standard IP packet (for example ping-of-death). Such an attack would generally have lower volumes of data. Unless some exploits exist at the victim hosts, which have not been fixed, a DoS attack should not pose a real threat to high-end services on today’s Internet.

DDoS (Distributed Denial of Service) attacks would, usually, be generated by a very large number of hosts. These hosts might be amplifiers[1] or reflectors[2] of some kind, or even might be “zombies” (agent program, which connects back to a pre-defined master hosts) who were planted on remote hosts and have been waiting for the command to “attack” a victim. It is quite common to see attacks generated by hundreds of hosts, generating hundreds of megabits per second floods.

The main tool of DDoS is bulk flooding, where an attacker or attackers flood the victim with as many packets as they can in order to overwhelm the victim. The best way to demonstrate what a DDoS attack does to a web server is to think on what would happen if all the population of a city decided at the same moment to go and stand in the line of the local shop. These are all legitimate requests for service – all the people came to buy something, but there is no chance they would be able to get service, because they have a thousand other people standing in line before them!

DDoS attacks require a large number of hosts attacking together at the same time (see figure 1). This can be accomplished by infecting a large number of Internet hosts with a “zombie”. This way, an attacker can be anyone with a certain knowledge and access privilege with the master host (such as the correct password to an Internet Relay Chat (IRC) channel). All he has to do is enter a few commands, and the whole zombie army would wake up and mount a massive attack against the victim of his or hers choice. [5]

The zombie program can be planted on the infected hosts in a variety of ways, such as attachment to spam email, the latest cool flash movie, a crack to a game, or even the game itself. Communication from the zombie to its master can be hidden as well by using standard protocols such as HTTP, IRC, ICMP or even DNS.

[1] System that is able to drastically increase the volume of attacking traffic. This can be accomplished with the use of broadcast addresses as the return destination of packets. Attacks that use amplifiers are also known as magnification attacks.

[2] A reflector is any IP host that will return one or more packets for each packet received. So, for example, all Web servers, DNS servers, and routers are reflectors, since they will return SYN ACKs or RSTs in response to SYN or other TCP packets. The same is true for query replies in response to query requests, and ICMP Time Exceeded or Host Unreachable messages in response to particular IP packets.

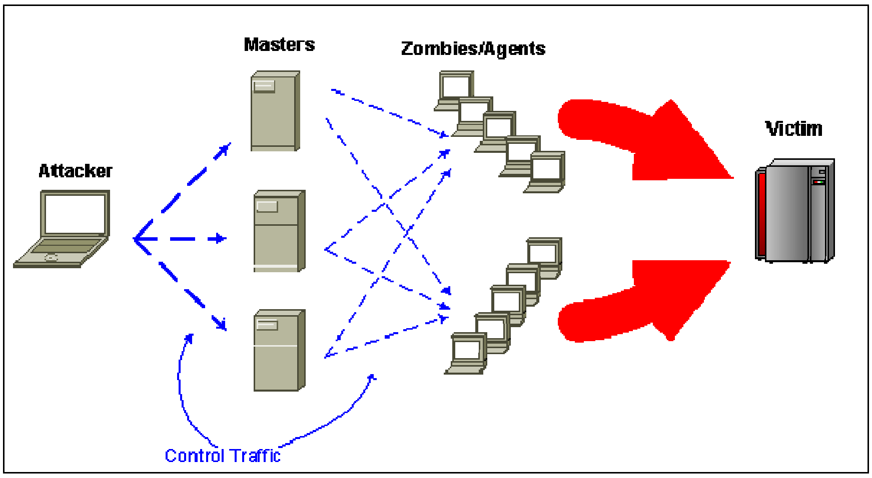


Figure 1: Description of a DDoS attack

DDoS attacks are quite common today, and they pose the main threat to public services because when a distributed attack is being generated against an Internet service, it is quite hard to block thousands of hosts sending flood data. This can be particularly painful if attacking packets are legitimate requests, since they cannot be easily associated to a DDoS attack.

Another aspect of most DDoS is that they consume a vast amount of resources from the network infrastructure, such as ISP networks and network equipment. This fact makes such attacks even more troublesome, because a single attack targeted against a minor web server, might bring the whole ISP's network down, and with it affect service for thousands of users.

3.2. Steps to Perform an Attack

Actually, the majorities of denial of service attacks are of distributed type, and have as basis flooding of large quantities of packets. Moreover, used packets might be changed to increase the harmfulness of the attack. Following, is a description of how to perpetrate a DDoS attack.

Today, in order to be able to generate a real DDoS overload attack it is not enough to have a few computers connected to Internet via a T1 leased line connection. Even a DS3 link might not be enough to bring a major web site down. In order to really be able to generate a massive amount of data in order to overload such a server the attacker would require a large number of hosts, each with a decent connection to the Internet. Summing up flood attacks from hundreds or even thousands of hosts can eventually generate a flood of hundreds of Mbps all directed against a single host or service.

Such a massive stream of data can overwhelm almost any system, including the network equipments, circuits and finally the servers themselves, even if a load balancer is being used. It is quite obvious that such attacks usually hit not only the victim of the attack, but also affect the close-by Internet area, because such amounts of traffic would overload many circuits and might crash the routers providing service to other clients as well.

Most of such attacks operate by building a large “army” of zombies which are spread all over the Internet. This army is composed of compromised Internet hosts which have a “zombie” or a Trojan[3] program installed on them. In order to create such a collection of hosts a way must be found to break into a large number of systems, and install a new program on these hosts.

After installing the software it has to be able to contact some central location in order to receive commands and maybe even software updates. This control channel would enable the attacker to initiate DDoS attacks on any Internet host whenever it is desired [6].

There have been several means of spreading such zombie software on the Internet. The simplest way is to break in into systems using known (or even better – unknown) security holes and manually installing the software. This method works just fine, but it’s slow and cumbersome. There are many other ways to distribute Trojan programs. For example a hacker can write a nice small free game, and put the Trojan’s installer inside. Now all that has to be done is to make sure that the link to the game is famous enough and wait for people to download it. Any person who would download the game and run it would install the zombie Trojan on his or her computer, adding it to the zombie army waiting for commands. The carrier program can take any shape and form, as long as it would attract enough people and make them run it on their computers. It has become quite common to find MP3 songs and other media files to carry viruses and Trojans inside.

Other ways of deployment have been seen on the Internet. Many worms[4] have been introduced into the Internet with a single objective in mind – spread as widely and as quickly as possible. For example, one of these worms was the Code Red worm [7]. Code Red was a malicious Internet worm which was propagating through the Internet, using vulnerabilities found in Microsoft Internet Information Service (IIS) servers.

After a Trojan has been installed on some host, it has to create a channel of communication with its “master” in order to receive commands and maybe even software updates. This functionality is not a must, but it would make a Trojan much more effective and the trouble of spreading it more worth while. A Trojan without such functionality can be used for a pre-defined set of tasks, but after it has finished, it would not serve any purpose.

A Trojan may use a large number of ways to communicate back to its master. The easiest way would be to open a TCP connection to a predefined host, and use this connection to receive instructions. This way of communication makes the Trojan quite vulnerable, because it would leave a very obvious trail behind it. Running the ‘netstat’ command on the infected computer would reveal the connection and with it the presence of the Trojan and the IP address of the master node. In order to hide the connection, the Trojan might use well-used protocols, such as HTTP or IRC.

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[3] A destructive program that masquerades as a benign application. Unlike viruses, Trojan horses do not replicate themselves but they can be just as destructive. One of the most insidious types of Trojan horse is a program that claims to rid your computer of viruses but instead introduces malicious code onto your computer.

[4] A program or algorithm that replicates itself over a computer network and usually performs malicious actions, such as using up the computer's resources and possibly shutting the system down.

By using HTTP, the Trojan can open an HTTP connection to a pre-defined web server, and use a specialized CGI page to post information to the server, and request new commands and data. Such a connection might be lost between other normal HTTP connections. Also, the connection can be relatively short, and repeat once in a few minutes. This will ensure that the Trojan would be up to date, but stay hidden from the user.

Another common way to create the connection is use the IRC protocol. The Trojan would connect to a pre-defined IRC channel on some public IRC network. In such a way, any person with access to this IRC channel can send text messages to the Trojans, and program and activate attacks in minutes [6]. A famous Trojan who is known to operate in such a way is Sub7. In order to protect the master node, and make it harder for people to break into the system, it is quite common to encrypt the whole sessions using standard encryption software easily found on the Internet.

The type of attack generated by the Trojan can vary, and it depends on which tools the Trojan software is based on. Usually it would enable at least a few types of attacks, including TCP/UDP/ICMP floods. The master can control the type of the attack, the packet lengths, the destination IP and many other parameters. Virtually any kind of known flood attack can be mounted using such zombie Trojans.

Protecting against such attacks is quite difficult because the volume of the attack may be so huge, that it would saturate many circuits and block all available bandwidth at the victim's network area. This kind of attack can hardly be beaten by any technique which can be installed at the victim's facility. The amount of traffic would simply fill the connection to the ISP, and any devices placed behind it would have no way to deal with all the traffic.

3.2.1. Attack Identity

Usually, when someone wants to attack an Internet host, he would like to maintain anonymity in order to avoid prosecution or just to avoid being exposed. One of the means of keeping anonymity is using zombie hosts to do the dirty work. This way is quite secure, but it is possible to back track the original attacker via the zombie hosts or software [6]. Also the zombies themselves are exposed, and could be fixed quite quickly because the victim of the attack can report their real IP addresses to the owner or service provider.

Another way for the attacker to keep his anonymity is to use spoofed IP addresses, forging the source IP address of the attacks.

Using reflectors is another way to accomplish anonymity. The attacker would reflect the attack from other Internet hosts, and by that make it seem to the victim as if they are the attackers. Reflectors can be used by many attack types. A single attacker host as well as many zombie hosts can use reflectors in order to hide the attack sources (see figure 2).

The main problem with reflectors is that they can be very secure Internet hosts, and still be used as reflectors. Almost any host which offers services to the Internet can be used as a reflector because it follows the IP standard. The basic idea is exploiting standard protocols which have a request-response sequences build into them. The request would be sent from the attacker to the reflector, with the source IP set to the victim's address. The reflector would send the response to the victim, effectively reflecting the attack.

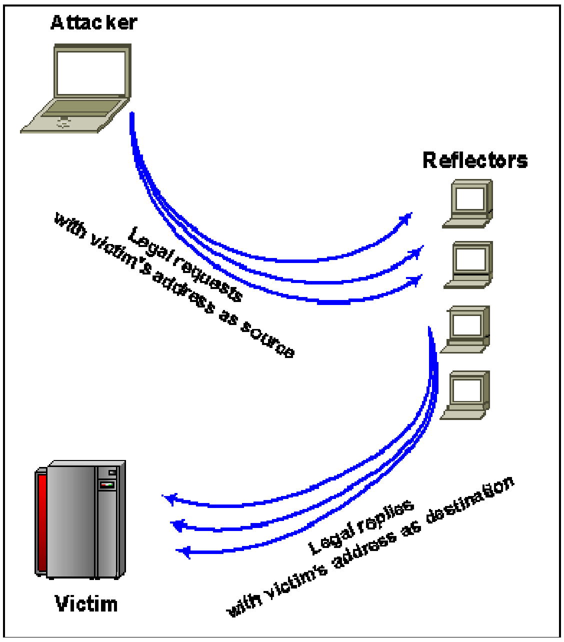

Figure 2: Reflector attack

3.3. Examples of Attacks

The attacks which are described in this document are only some of all those available on the Internet. Their common denominator is that they all use weaknesses or erroneous implementations of the TCP/IP protocol, or they utilize weaknesses in the specification of the TCP/IP protocol itself. Besides these particular exploiting attacks there is the always effective brute force attack that works well with the exploitation of weaknesses in the TCP/IP suite implementations and specifications.

The reminder of this section presents TCP/IP attacks, their impact on the network and whenever possible some solutions to protect the network from their occurrence.

3.3.1. SYN Flood Attack

When a system (called the client) attempts to establish a TCP connection to a system providing a service (the server), the client and server exchange a sequence of messages. This connection technique applies to all TCP connections – telnet, Web, email, etc.

The client system begins by sending a SYN message to the server, asking the server to open a connection. The server then acknowledges the SYN message by sending a SYN-ACK message to the client, meaning it accepts to open the connection from the client (the ACK part) and asking if the client agrees to open the connection in the opposite sense (the SYN part). The client then finishes establishing the connection by responding with an ACK message to server. The connection between the client and the server is then open, and the service-specific data can be exchanged between the client and the server. Figure 3 presents a view of this message flow.

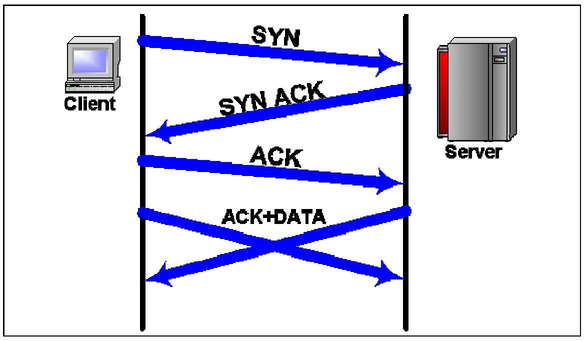

Figure 3: TCP three-way handshake

The potential for abuse arises at the point where the server system has sent an acknowledgment (SYN-ACK) back to client but has not yet received the ACK message. This is what we mean by half-open connection. The server has built in its system memory a data structure describing all pending connections. This data structure is of finite size, and it can be overflowed by intentionally creating too many partially-open connections.

Creating half-open connections is easily accomplished with IP spoofing. The attacking system sends SYN messages to the victim server system; these appear to be legitimate but in fact reference a client system that is unable to respond to the SYN-ACK messages. This means that the final ACK message will never be sent to the victim server system.

The half-open connections data structure on the victim server system will eventually exhaust; then the system will be unable to accept any new incoming connections until the table is emptied out. Normally there is a timeout associated with a pending connection, so the half-open connections will eventually expire and the victim server system will recover. However, the attacking system can simply continue sending IP-spoofed packets requesting new connections faster than the victim system can timeout the pending connections.

In most cases, the victim of such an attack will have difficulty in accepting any new incoming network connection. In these cases, the attack does not affect existing incoming connections nor the ability to originate outgoing network connections.

However, in some cases, the system may exhaust memory, crash, or be rendered otherwise inoperative.

The location of the attacking system is obscured because the source addresses in the SYN packets are often implausible. When the packet arrives at the victim server system, there is no way to determine its true source. Since the network forwards packets based on destination address, the only way to validate the source of a packet is to use input source filtering.

Any system connected to the Internet and providing TCP-based network services (such as a Web server, FTP server, or mail server) is potentially subject to this attack. Note that in addition to attacks launched at specific hosts, these attacks could also be launched against routers or other network server systems if these hosts enable (or turn on) other TCP services (e.g., echo). The consequences of the attack may vary depending on the system; however, the attack itself is fundamental to the TCP protocol used by all systems.

You should note that this type of attack does not depend on the attacker being able to consume your network bandwidth. In this case, the intruder is consuming kernel data structures involved in establishing a network connection. The implication is that an intruder can execute this attack from a dial-up connection against a machine on a very fast network.

A relatively small flood of bogus packets will tie up memory, CPU, and applications, resulting in shutting down a server.

Although some have described TCP SYN Flood as a bug in TCP/IP, it is more correctly a feature of the design. TCP/IP was designed for a friendly Internet, and a limited connection queue (collection of resources reserved per connection) has worked fine for years.

Early fixes have focused on increasing the length of the queues and reducing a timeout value. The timeout value controls how long an entry waits in the queue until an acknowledgement is received. The problem with simply making the queue longer is that there are actually many queues (one for each TCP server on the system – HTTP, FTP, SMTP, etc.), and lengthening the queues to very large values, for example, eight kilobytes, results in an operating system requiring enormous amounts of memory (over 100 megabytes for a system with 25 server applications).

Shortening the timeouts can also help when used with longer queue lengths because the spoofed packets get removed from the queues more quickly. However, shortening the timeouts also affects new outgoing connections, and remote users with slow links which may never get connected to the server.

Actually, several other countermeasures are available. Some of them include:

- To check periodically incomplete connection requests, and randomly clear connections that have not completed a three-way handshake. This will reduce the likelihood of a complete block due to a successful SYN attack, and allow legitimate client connections to proceed.
- To limit TCP SYN traffic rate.
- To install an IDS (Intrusion Detection System) capable of detecting TCP SYN flood attacks.
- To use circuit level firewalls (stateful inspection) to monitor the handshake of each new connection and maintain the state of established TCP connections. The filtering

system must be able to distinguish harmful uses of a network service from legitimate uses.

- To set a firewall to block all incoming packets with bad external IP addresses like 10.0.0.0 to 10.255.255.255, 127.0.0.0 to 127.255.255.255, 172.16.0.0 to 172.31.255.255, and 192.168.0.0 to 192.168.255.255 and all internal addresses.
- To modify the TCP implementation to reduce the amount of information stored for each in-progress connection.
- To verify the return route of each new connection. If it is different than the received packets, which is normal during this attack, connection should be dropped.

However, as some attacks have proved, if enough SYN packets are thrown at a site, any site can still be SYNed off the net.

3.3.2. TCP Flooding

Probably, whenever we have heard about TCP flooding attacks, we were talking about a TCP SYN flood attack. However, it is possible to experience a TCP flooding attack that is not taking advantage of the TCP three-way handshake. It is also possible to perpetrate a TCP flooding attack taking advantage of other TCP’s finite state or TCP’s flags.

TCP ACK flood

In this attack, a lot of TCP ACK packets are sent to victim to utilize its system and network resources. Depending on the OS, an open port or closed port might reply a TCP RESET packet, causing more traffics and workload on the victim and victim's network.

An evolution of this attack consists in flooding the victim with TCP ACK packets with spoofed source IP, random sequence number and random port number in the packet.

NULL flood

This TCP flooding attack is accomplished with TCP packet's TCP flag all set to 0. This is where the 'NULL' means. The victim might ignore it, consume system resource or crash completely depending on the operating system implementation.

RST Attack

There is also a quite similar DoS attack called RST. The TCP Reset flag is used to abort TCP connections, usually to signify an irrecoverable error. When receiving such a packet, the host deletes the connection and frees data structures. To prevent a bad utilization of this flag, only RST messages that fit in the sequence number window are accepted.

By sending RST packets with correct sequence numbers (packets can be sniffed from the network) and with a spoofed IP address, an active TCP connection can be torn down quite effectively. The purpose and effect of this kind of attack is similar to SYN flood DoS attack, however it is not necessary to send large volumes of information to accomplish an effective cutting of services at the attacked machine.

3.3.3. UDP Flooding

The UDP flooding attack belongs to the class of brute force attacks, and it is perpetrated by programs that launch denial-of-service attacks by creating a "UDP packet storm" either on a system or between two systems.

This attack is possible when an attacker sends an UDP packet to a random port on the victim system. When the victim system receives an UDP packet, it will determine what application is waiting on the destination port. When it realizes that there is no application that is waiting on the port, it will generate an ICMP packet of destination unreachable to the forged source address. If enough UDP packets are delivered to ports on victim, the system will go down.

An attack on one host causes that host to perform poorly. An attack between two hosts can cause extreme network congestion in addition to adversely affecting host performance.

Anyone with network connectivity can cause a denial of service. This attack does not enable them to gain additional access.

To dam up UDP floods it is just necessary to block all UDP services request that will not be used. Programs that need UDP will still work, unless of course, the sheer volume of the attack mauls the Internet connection.

3.3.4. ICMP Flood

Like the other flooding attacks, this one is accomplished by broadcasting a bunch of ICMP packets, usually ping packets. The idea is to send so much data to the system that it slows down so much and gets disconnected due to timeouts.

Particularly, Ping flood attacks attempt to saturate a network by sending a continuous series of ICMP echo requests over a high-bandwidth connection to a target host on a lower-bandwidth connection. The receiver must send back an ICMP echo reply for each request.

3.3.5. Smurf

Smurf attacks send ICMP echo requests (pings) to the broadcast addresses of well-populated "intermediate" networks. The source IP addresses of attack packets are spoofed to match the address of an attacked host on a target network. After receiving a copy of the echo request, each host in the intermediate network responds with an echo reply to the attacked host, flooding both the host and its network.

These attacks can result in large amounts of ICMP echo reply packets being sent from an intermediary site to a victim, which rapidly exhausts the bandwidth available to the target, effectively denying its services to legitimate users and causing network congestion or outages. These attacks have been referred to as "smurf" attacks because the name of one of the exploit programs attackers use to execute this attack is called "smurf."

The two main components to the smurf denial-of-service attack are the use of forged ICMP echo request packets and the direction of packets to IP broadcast addresses.

In the "smurf" attack, attackers are using ICMP echo request packets directed to IP broadcast addresses from remote locations to generate denial-of-service attacks. There are three parties in these attacks: the attacker, the intermediary, and the victim (note that the intermediary can also be a victim).

The intermediary receives an ICMP echo request packet directed to the IP broadcast address of their network, which will be an amplifier. If the intermediary does not filter ICMP traffic directed to IP broadcast addresses, many of the machines on the network will receive this ICMP echo request packet and send an ICMP echo reply packet back. When (potentially) all the machines on a network respond to this ICMP echo request, the result can be severe network congestion or outages. Figure 4 represents how smurf is executed.

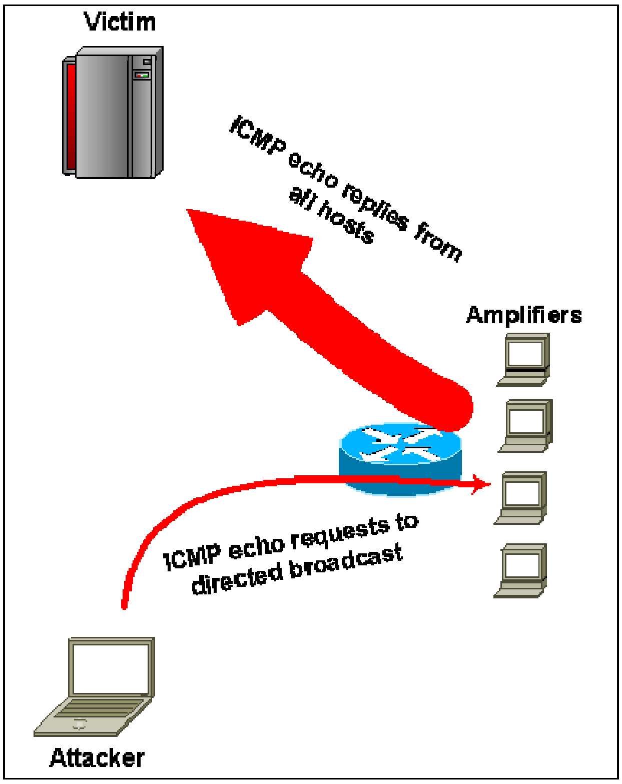

Figure 4: Representation of Smurf attack

When the attackers create these packets, they do not use the IP address of their own machine as the source address. Instead, they create forged packets that contain the spoofed source address of the attacker's intended victim. The result is that when all the machines at the intermediary's site respond to the ICMP echo requests, they send replies to the victim's machine. The victim is subjected to network congestion that could potentially make the network unusable. Even though the intermediary was not labeled as a "victim," the intermediary can be victimized by suffering the same types of problem that the "real victim" does in these attacks.

Attackers have developed automated tools that enable them to send these attacks to multiple intermediaries at the same time, causing all of the intermediaries to direct their responses to the same victim. Attackers have also developed tools to look for network routers that do not filter broadcast traffic and networks where multiple hosts respond. These networks can then subsequently be used as intermediaries in attacks.

Both the intermediary and victim of this attack may suffer degraded network performance, both on their internal networks or on their connection to the Internet. Performance may be degraded to the point that the network cannot be used, since all the available bandwidth is being consumed.

A significant enough stream of traffic can cause serious performance degradation for small and mid-level ISPs that supply service to the intermediaries or victims. Larger ISPs may see backbone degradation and peering saturation.

Fortunately, this type of attack can be blocked by just setting the router to ignore broadcast addressing and setting the firewall to ignore ICMP requests.

3.3.5. Ping of Death

The TCP/IP specification (the basis for many protocols used on the Internet) allows for a maximum packet size of up to 65536 octets (1 byte = 8 bits of data), containing a minimum of 20 bytes of IP header information and 0 or more bytes of optional information, with the rest of the packet being data. It is known that some systems will react in an unpredictable fashion when receiving oversized IP packets. Reports indicate a range of reactions including crashing, freezing, and rebooting.

In particular, some reports indicate that Internet Control Message Protocol (ICMP) packets issued via the "ping" command have been used to trigger this behavior. The "ping" command can be used to construct oversized ICMP datagrams (which are encapsulated within an IP packet), taking advantage that many ping implementations by default send ICMP datagrams consisting only of the 8 bytes of ICMP header information, but allow the user to specify a larger packet size if desired.

An attacker sends an ICMP ECHO request packet that is much larger than the maximum IP packet size to victim. Since the received ICMP echo request packet is bigger than the normal IP packet size, the victim cannot reassemble the packets. The OS may be crashed or rebooted as a result.

The Ping of Death is a typical TCP/IP implementation attack. In this assault, the DDoS attacker creates an IP packet that exceeds the IP standard's maximum 65,536-byte size. When this large packet arrives, it crashes systems that are using a vulnerable TCP/IP stack. No modern operating system or stack is vulnerable to the simple Ping of Death, but it was a long-standing problem with Unix systems.

3.3.6. Teardrop

The Teardrop, though, is an old attack that relies on poor TCP/IP implementation that is still around. It works by interfering with how stacks reassemble IP packet fragments. The trick here is that as IP packet are sometimes broken up into smaller chunks, each fragment still has the original IP packet's header, and field that tells the TCP/IP stack what bytes it contains. When it works right, this information is used to put the packet back together again. What happens with Teardrop though is that your stack is buried with IP fragments that have overlapping fields. When the stack tries to reassemble them, it cannot do it, and if it does not know to toss these trash packet fragments out, it can quickly fail. Most systems know how to deal with Teardrops now and a firewall can block Teardrop packets in return for a bit more latency on network connections since this makes it disregard all broken packets. Of course, if you throw a ton of Teardrop busted packets at a system, it can still crash

Many other variants such as Targa, SynDrop, Boink, Nestea Bonk, TearDrop2 and NewTear are available to accomplish this kind of attack.

3.3.7. Land

A LAND attack consists of a stream of TCP SYN packets that have the source IP address and TCP port number set to the same value as the destination address and port number (i.e., that of the attacked host). Some implementations of TCP/IP cannot handle this theoretically impossible condition, causing the operating system to go into a loop as it tries to resolve repeated connections to itself.

Service providers can block LAND attacks that originate behind aggregation points by installing filters on the ingress ports of their edge routers to check the source IP addresses of all incoming packets. If the address is within the range of advertised prefixes, the packet is forwarded; otherwise it is dropped.

3.3.8. Echo/Chargen

The character generator (chargen) service is designed to simply generate a stream of characters. It is primarily used for testing purposes. Remote users/intruders can abuse this service by exhausting system resources. Spoofed network sessions that appear to come from that local system's echo service can be pointed at the chargen service to form a "loop." This session will cause huge amounts of data to be passed in an endless loop that causes heavy load to the system. When this spoofed session is pointed at a remote system's echo service, this denial of service attack will cause heavy network traffic/overhead that considerably slows down the network. It should be noted that an attacker does not need to be on your subnet to perform this attack as he/she can forge the source addresses to these services with relative ease.

3.3.9. Naptha Attack

The number and type of resources that an attacker can target for a denial-of-service attack are many and varied. The Naptha work highlights a set of them for which some specific defenses exist.

In general, any system that allows critical resources to be consumed without bound is subject to denial-of-service attacks. Naptha and similar network attacks are more dangerous for several reasons:

- They can be done "asymmetrically" – that is, the attacker can consume vast amounts of a victim's limited resource without a commensurate resource expenditure.
- In combination with other vulnerabilities or weaknesses, they can be done anonymously.
- They can be included in distributed denial-of-service tools.

Naptha attacks mainly exploit weaknesses in the way some TCP stacks and applications handle large numbers of connections, creating a resource starvation attack. Particularly with Naptha attacks, instead of actually creating connections to the victim, the Naptha tool fools the victim's operating system into thinking it sees valid network connections. The victim's server application waits for a valid request, or receives a request and attempts to send the data, which instead languishes in the operating system because it cannot be sent. Because the connections are simulated instead of real, an attacker can launch a devastating attack with little in the way of resources.

If an unusual number of connections in a particular state are noticed, it may be an indication of this type of attack. The definition of "unusual" in this case depends largely on the types of services offered by the attacked machine. For example, a large number of connections in the ESTABLISHED state on a web server may simply be an indication of a busy web server. Understanding the normal usage patterns of services offered may help to distinguish an attack from ordinary activity. Many operating systems offer a netstat utility that is useful for examining the state of connections.

3.3. Some Solutions to DoS Attacks

The way DoS and DDoS attacks are perpetrated, by exploiting limitations of protocols and applications, is one of the main factors why they are continuously evolving, and because of that presenting new challenges on how to combat or limit their effects.

Even if all of these attacks cannot be completely avoided, some basic rules can be followed, to protect the network against some, and to limit the extent of the attack [3][4] :

- Make sure the network has a firewall up that aggressively keeps everything out except legal traffic.
- Implement router filters. This will lessen the exposure to certain denial-of-service attacks. Additionally, it will aid in preventing users on network from effectively launching certain denial-of-service attacks.
- Install patches to guard against TCP/IP attacks. This will substantially reduce the exposure to these attacks but may not eliminate the risk entirely.

- Disable any unused or unneeded network services. This can limit the ability of an intruder to take advantage of those services to execute a denial-of-service attack.
- Observe the system performance and establish baselines for ordinary activity. Use the baseline to gauge unusual levels of disk activity, CPU usage, or network traffic.
- Keep the anti-viral software up to date. This will prevent the site becoming a home for DDoS agents like TFN.
- Invest in redundant and fault-tolerant network configurations.

Besides the rules listed above, it is important for a network administrator, or even a machine administrator, to keep current on the latest DDoS developments.

Also, since there is no silver bullet for DDoS attacks several companies offer program and services that can help a network administrator to manage DDoS assaults. Essentially, these corporate approaches consist of intense real-time monitoring of the network looking for telltale signs of incoming DDoS attacks.