Chair for Network Architectures and Services
Department of Informatics
TU München – Prof. Carle

Network Security

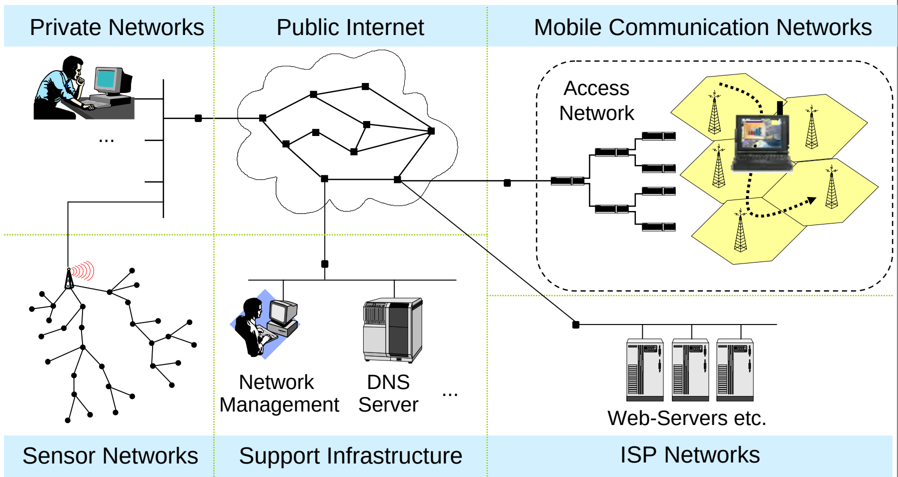
Chapter 8

System Vulnerabilities and Denial of Service Attacks

System Vulnerabilities and Denial of Service Attacks

- Introduction and Threat Overview
- Denial of Service Threats
- DoS Attacks: Classification
- System Vulnerabilities
- Honeypots
- Upcoming Challenges

A High Level Model for Internet-Based IT-Infrastructure



System Vulnerabilities and Denial of Service Attacks

- Introduction and Threat Overview
- Denial of Service Threats
- DoS Attacks: Classification
- System Vulnerabilities
- Honeypots
- Upcoming Challenges

Denial of Service

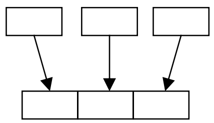
- What is Denial of Service?
  - *Denial of Service (DoS) attacks aim at denying or degrading legitimate users' access to a service or network resource, or at bringing down the servers offering such services*
- Motivations for launching DoS attacks:
  - Hacking (just for fun, by "script kiddies", ...)
  - Gaining information leap (→ 1997 attack on bureau of labor statistics server; was possibly launched as unemployment information has implications to the stock market)
  - Discrediting an organization operating a system (i.e. web server)
  - Revenge (personal, against a company, ...)
  - Political reasons ("information warfare")
  - ...

Denial of Service Attacking Techniques

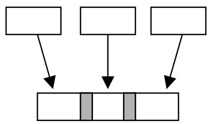
- *Resource destruction* (disabling services):
  - Hacking into systems
  - Making use of implementation weaknesses as buffer overflow
  - Deviation from proper protocol execution
- *Resource depletion* by causing:
  - Storage of (useless) state information
  - High traffic load (requires high overall bandwidth from attacker)
  - Expensive computations ("expensive cryptography"!)
  - Resource reservations that are never used (e.g. bandwidth)
- Origin of malicious traffic:
  - Genuineness of source addresses: either genuine or forged
  - Number of sources:
    - single source, or
    - multiple sources *(Distributed DoS, DDoS)*

Examples: Resource Destruction

- Ping-of-Death:
  - Maximum size of TCP/IP packet is 65536 bytes
  - Oversized packet may crash, freeze, reboot system
- Teardrop:
  - Fragmented packets are reassembled using the Offset field.
  - Overlapping Offset fields might cause system to crash.



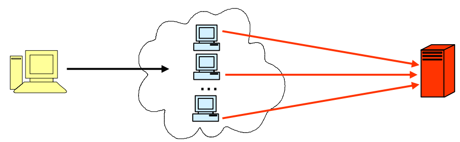
Normal Behavior



Teardrop Attack

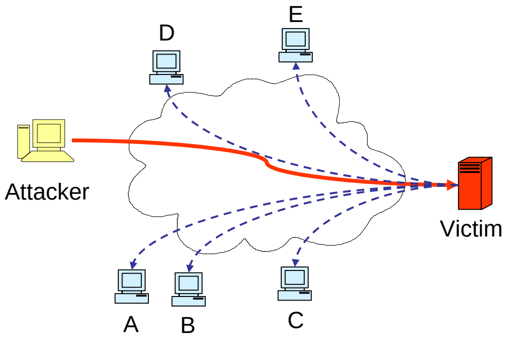
Resource Depletion Example 1: Abusing ICMP

- Two main reasons make ICMP particular interesting for attackers:
  - It may be addressed to broadcast addresses
  - Routers respond to it
- The *Smurf* attack - ICMP echo request to broadcast:
  - An attacker sends an ICMP echo request to a broadcast address with the source addressed forged to refer to the victim
    - local broadcast: 255.255.255.255;
    - directed broadcast: (191.128.0.0/24) 191.128.0.255
  - Routers (often) allow ICMP echo requests to broadcast addresses
  - All devices in the addressed network respond to the packet
  - The victim is flooded with replies to the echo request
  - With this technique, the network being abused as an (unaware) attack amplifier is also called a *reflector network:*



Resource Depletion Example 2: TCP-SYN Flood

- Category *Storage of useless state information:*
  - Here: TCP-SYN flood attack

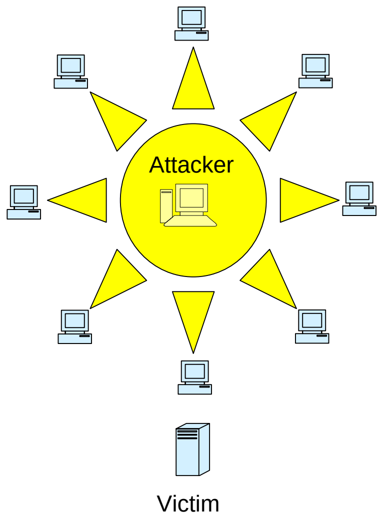


Connection Table

A
B
C
D
E
...

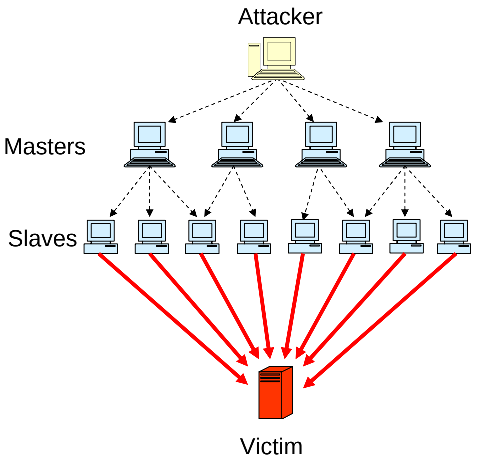
- TCP SYN packets with forged source addresses ("SYN Flood")
- TCP SYN ACK packet to assumed initiator ("Backscatter")

Resource Depletion with Distributed DoS (1)



- Category *Overwhelming the victim with traffic*
- Attacker intrudes multiple systems by exploiting known flaws
- Attacker installs DoS-software:
  - „Root Kits" are used to hide the existence of this software
- DoS-software is used for:
  - Exchange of control commands
  - Launching an attack
  - Coordinating the attack

Resource Depletion with Distributed DoS (2)

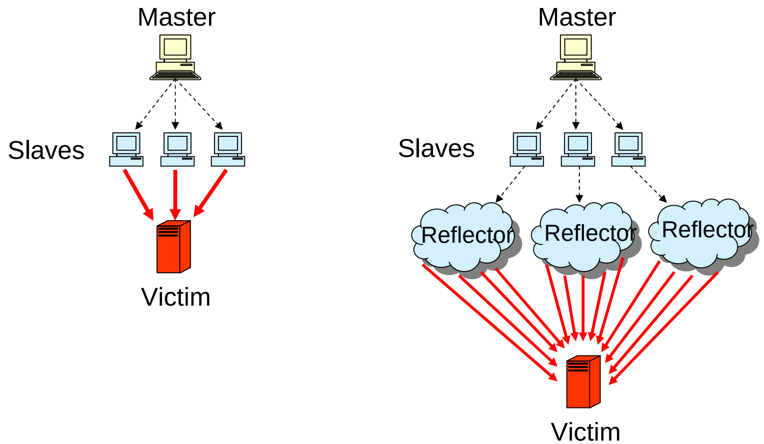


Control Traffic — Attack Traffic

- The attacker classifies the compromised systems in:
  - Master systems
  - Slave systems
- Master systems:
  - Receive command data from attacker
  - Control the slaves
- Slave systems:
  - Launch the proper attack against the victim
- During the attack there is no traffic from the attacker

Resource Depletion with Distributed DoS (3)

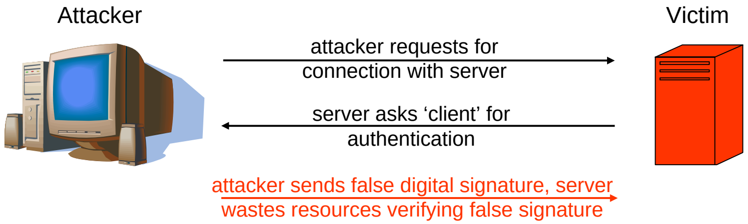
- Different Attack Network Topologies



a.) Master-Slave-Victim b.) Master-Slave-Reflector-Victim

Resource Depletion with CPU Exhaustion

- Category *CPU exhaustion by causing expensive computations:*
  - Here: attacking with bogus authentication attempts



  - The attacker usually either needs to receive or guess some values of the second message, that have to be included in the third message for the attack to be successful
  - Also, the attacker, must trick the victim *repeatedly* to perform the expensive computation in order to cause significant damage

➡ Be aware of DoS-Risks when introducing security functions into protocols!!!

System Vulnerabilities and Denial of Service Attacks

DoS Attacks: Classification

- Classification by exploited vulnerability
  - Software vulnerability attacks
  - Protocol attacks
  - Brute-Force / flooding attacks
- Classification by attack rate dynamics:
  - Continues rate
  - Variable rate:
    - Increasing
    - Fluctuating
- Classification by impact:
  - Disruptive
  - Degrading

Classification of DoS Attacks by Exploited Vulnerability (1)

- Based on the vulnerability that is targeted during an attack, DoS attacks can be classified into:
    - Software vulnerability attacks
    - Protocol attacks
    - Brute-Force / flooding attacks
- Some attacks can be classified into more than one of these categories. (see below)
- Software vulnerability attacks:
  - Here, software bugs are exploited.
  - Examples:
    - Cisco 7xx attack: Some Cisco 7xx routers were crashed by connecting with "Telnet" and typing a very long password
      $\Rightarrow$ a password buffer overflow.
    - Ping-of-Death
    - Teardrop

Classification of DoS Attacks by Exploited Vulnerability (2)

- Protocol Attacks
  - Exploits a specific feature or implementation bug of the protocol.
  - Examples include:
    - TCP SYN flood attacks
    - Authentication server attacks
    - Ping-of-death
    - Teardrop
- Brute-force Attacks / Flooding attacks:
  - The victim is overwhelmed with a vast amount of seemingly legitimate transactions.
  - Brute-force attacks are further classified into two sub-categories: (see also next slide for more details)
    - Filterable attacks
    - Non-filterable attacks

Classification of DoS Attacks by Exploited Vulnerability (3)

- Filterable attacks:
  - The flood packets are not critical for the service offered by the victim, and therefore can be filtered.
  - Example: UDP flood or ICMP request flood on a web server.
- Non-filterable attacks:
  - The flood packets request legitimate services from the victim.
  - Examples include:
    - HTTP request flood targeting a Web server
    - CGI request flood
    - DNS request flood targeting a name server
  - Filtering all the packets would be an immediate DoS attack to both attackers and legitimate users.
- The victim might mitigate the effect of protocol attacks, by modifying the deployed protocol.
- However, the victim is helpless against brute-force attacks if they use legitimate services.

Classification of DoS Attacks by Attack Rate Dynamics

- Based on the attack rate dynamics that is targeted during an attack, DoS attacks can be classified into:
    - Continuous Rate Attacks
    - Variable Rate Attacks
- Continuous Rate Attacks:
  - The most frequent kind of attack
  - When the attack is launched, agent machines generate attack packets with a large constant rate.
  - The sudden packet flood disrupts the victim's services quickly.
  - The attack may be noticed quickly.
- Variable Rate Attacks:
  - Vary the attack rate to avoid detection
  - The attack rate might be increasing over a long time or even fluctuating, which makes detection even harder.

Classification by Impact

- Disruptive:
  - The goal is to fully deny the victim's service to its clients
  - The most common category of attacks
- Degrading:
  - A portion of the victim's resources (e.g. 30%) are occupied by the attackers.
  - Can remain undetected for a signification time period
  - Customers experience slow response times or now service during high load periods.
  - Customers go to an other Service Provider.

System Vulnerabilities: Basic Attacking Styles

- Origin of attacks:
  - Remote attacks: attacker breaks into a machine connected to same network, usually through flaw in software
  - Local attacks: malicious user gains additional privileges on a machine (usually administrative)
- Main attacking techniques:
  - *Buffer overflow:*
    - Intentional manipulation of program state by causing an area of memory to be written beyond its allocated limits
  - *Race condition:*
    - Exploiting non-atomic execution of a series of commands by inserting actions that were "unforeseen" by the programmer
  - *Exploiting trust in program input / environment:*
    - It is often possible to maliciously craft input / environment variables to have deleterious side effects
    - Programmers are often unaware of this

Identifying Vulnerable Systems with Port Scans (1)

- Background
  - Identification of vulnerable systems / applications in order to identify systems to compromise
  - Automated distribution of worms
- Scan types
  - Vertical scan: sequential or random scan of multiple (5 or more) ports of a single IP address from the same source during a one hour period
  - Horizontal scan: scan of several machines (5 or more) in a subnet at the same target port from the same source during a one hour period
  - Coordinated scan: scans from multiple sources (5 or more) aimed at a particular port of destinations in the same /24 subnet within a one hour window; also called distributed scan
  - Stealth scan: horizontal or vertical scans initiated with a very low frequency to avoid detection

System Vulnerabilities and Denial of Service Attacks

Honeypots (1)

- A *Honeypot* is a resource, which pretends to be an attacked or compromised real target, but is a redundant or isolated resource where the attacker can not do any real damage.
- Motivation
  - *Get to know the "enemy"!!*
- Low-Interaction Honeypots:
  - Emulated services (e.g. FTP) and emulated operations systems
  - Easier to deploy and maintain
  - Can log only limited information
  - Limited capture of activities
- High-Interaction Honeypots
  - Involves real operation systems and real applications
  - Can capture extensive amount of information
  - Problem: Attackers can use this real operating system to attack non-honeypot systems.

Honeypots (2)

- Honeypots can capture unknown attacks.
- Honeypots can slow down or even stop the spread of worms.
  - Worms scan for vulnerabilities, and take over the system.
  - A honeypot can slow the scanning capabilities of the worm and eventually stop it.
    - scan unused IP spaces
    - TCP window size is zero.
- Real systems can not be taken offline for analysis.
  - They are often too critical.
  - They contain too much data pollution involved such as it is difficult to determine what the attacker actually did.
- Honeypots can quickly and easily be taken offline for a full forensic analysis.
- High-interaction honeypots are a very effective solution to prevent intrusion.
- They provide in-depth knowledge about the behavior of attackers.

System Vulnerabilities and Denial of Service Attacks

Some Upcoming Challenges

- The introduction of Internet protocols in classical and mobile telecommunication networks also introduces the Internet's DoS vulnerabilities to these networks
- Programmable end-devices (PDAs, smart phones) may constitute a large base of possible slave nodes for DDoS attacks on mobile networks
- Software defined radio implementation may even allow new attacking techniques:
  - Hacked smart phones answer to arbitrary paging requests
  - Unfair / malicious MAC protocol behavior
  - ...
- The ongoing integration of communications and automation ($\rightarrow$ sensor/actuator networks) may enable completely new DoS threats