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

Network Security

Chapter 10

System Vulnerabilities and Denial of Service Attacks

Acknowledgments

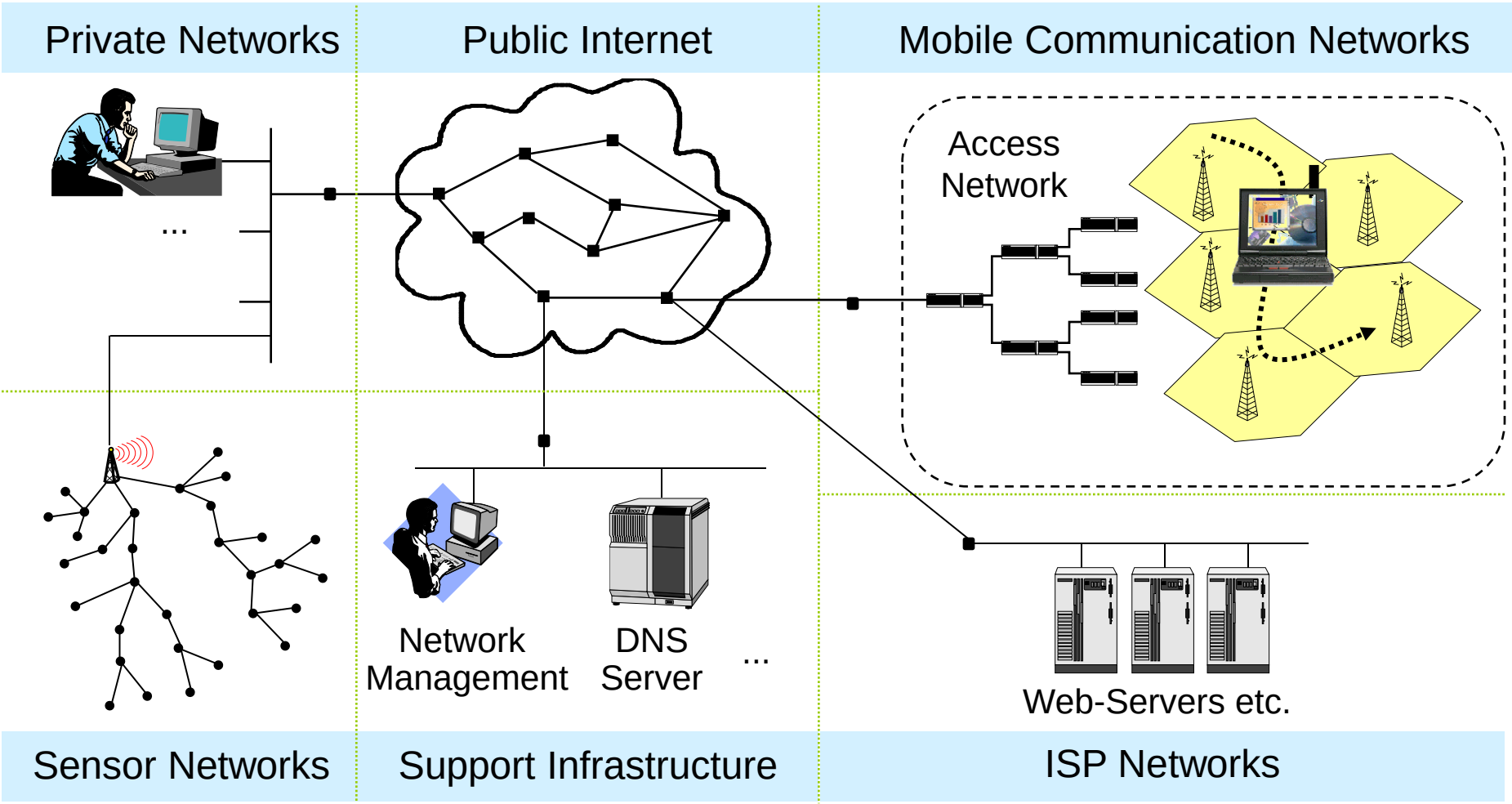
This course is based to a significant extend on slides provided by Günter Schäfer, author of the **book "Netzsicherheit - Algorithmische Grundlagen und Protokolle"**, available in German from **dpunkt Verlag**. The English version of the book is entitled “Security in Fixed and Wireless Networks: An Introduction to Securing Data Communications” and is published by Wiley is also available. We gratefully acknowledge his support.

The slides by Günter Schäfer have been partially reworked by Heiko Niedermayer, Ali Fessi, Ralph Holz and Georg Carle.

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



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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 ($\rightarrow$ 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")
  - ...

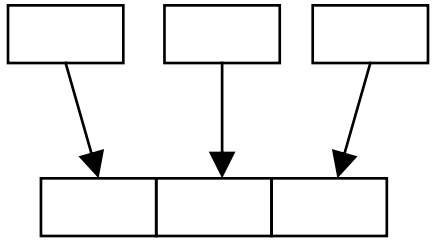
Denial of Service Attacking Techniques

- *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)*

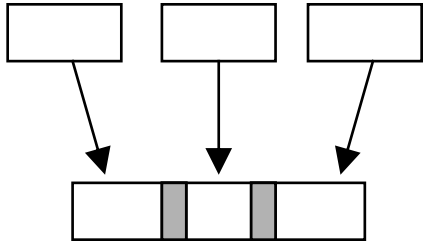
Examples: Resource Destruction

- 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.



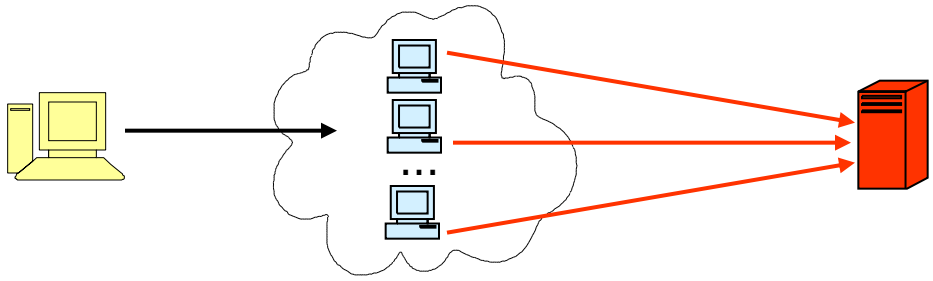
Normal Behavior



Teardrop Attack

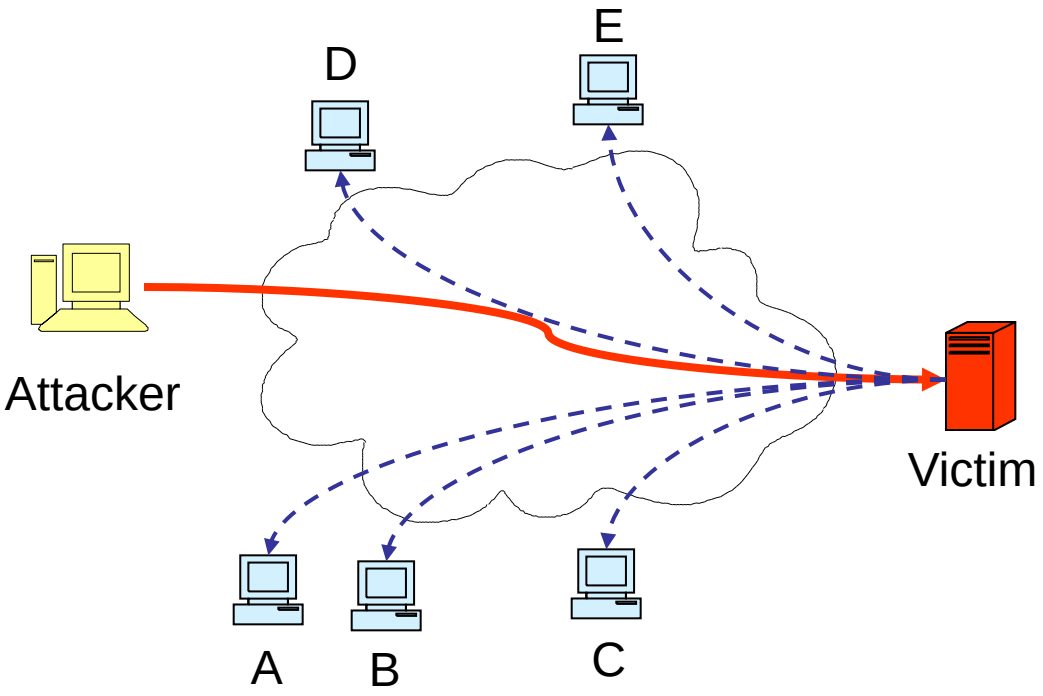
Resource Depletion Example 1: Abusing ICMP

- 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



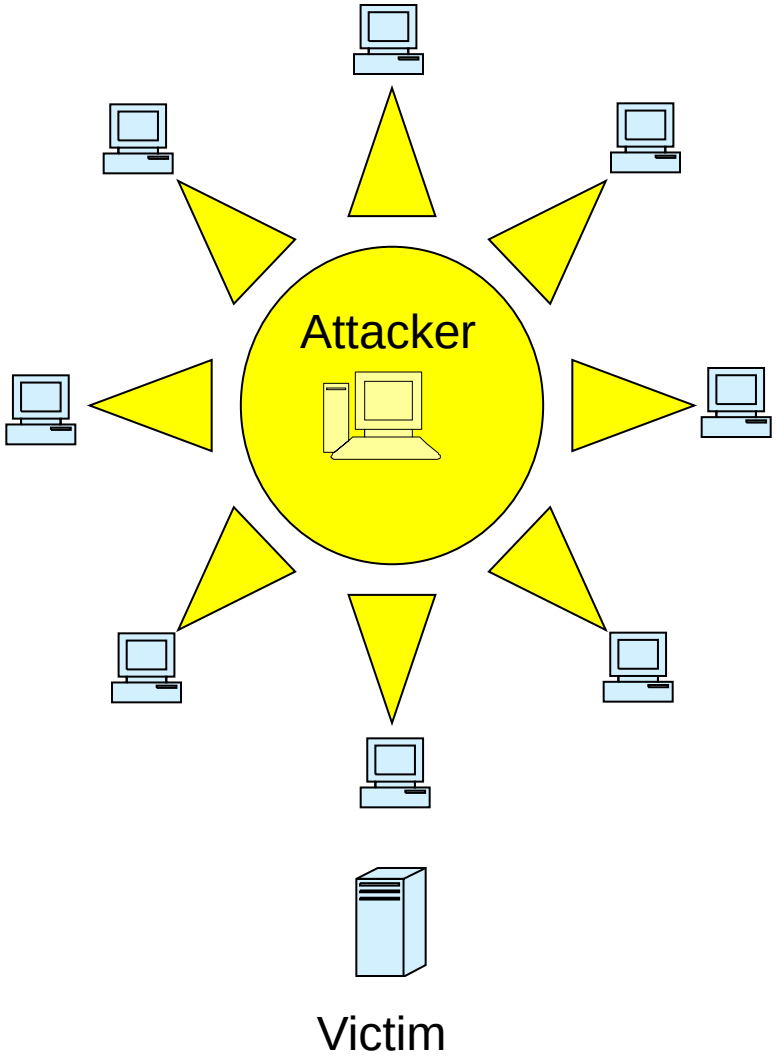
Connection Table

A
B
C
D
E
...

TCP SYN packets with forged source addresses (“SYN Flood”)

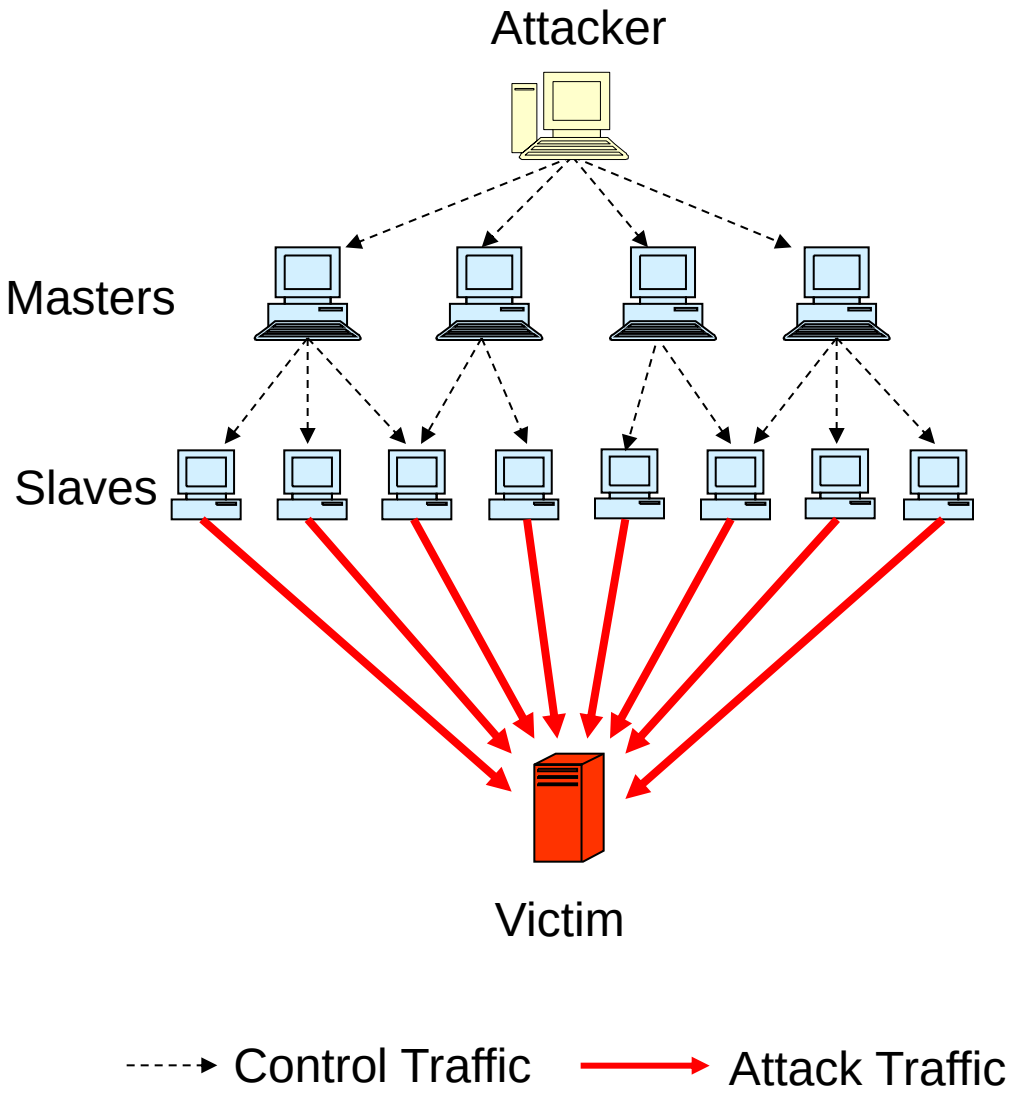
TCP SYN ACK packet to assumed initiator (“Backscatter”)

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

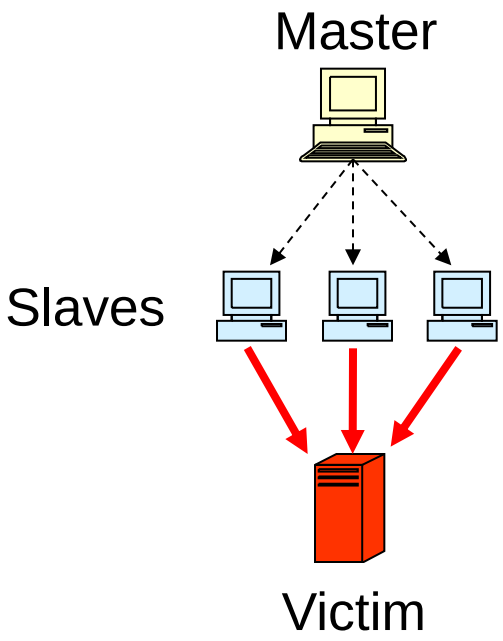
Resource Depletion with Distributed DoS (2)



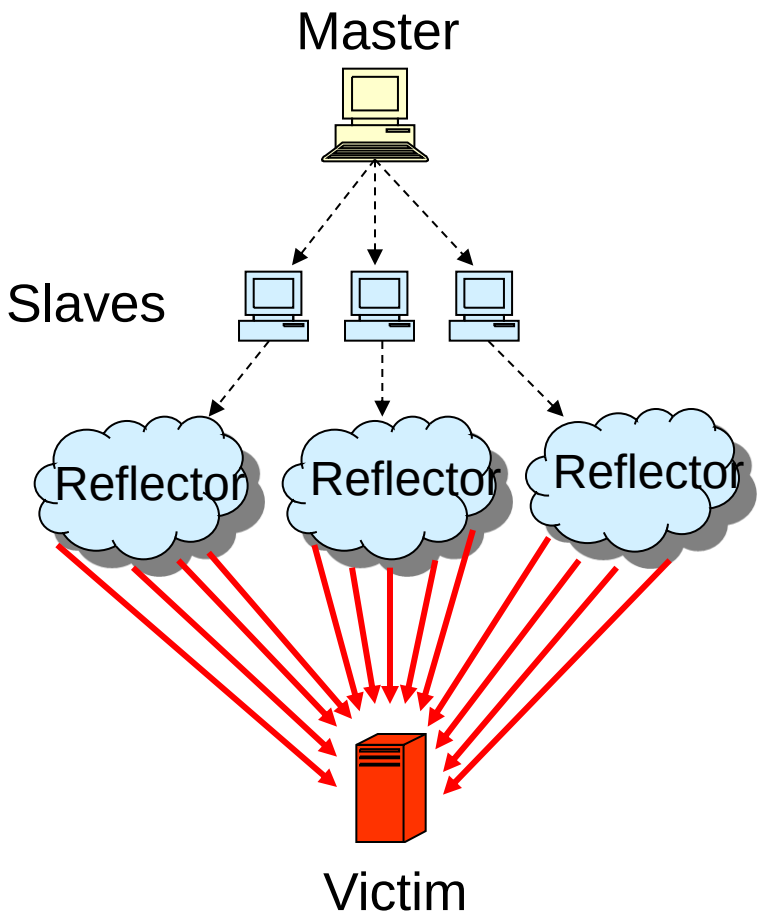
- The attacker classifies the compromised systems in:
  - Master systems
  - Slave systems
- Master systems:
  - Receive command data from attacker
  - Control the slaves
- Slave systems:
  - Launch the proper attack against the victim
- During the attack there is no traffic from the attacker

Resource Depletion with Distributed DoS (3)

- Different Attack Network Topologies



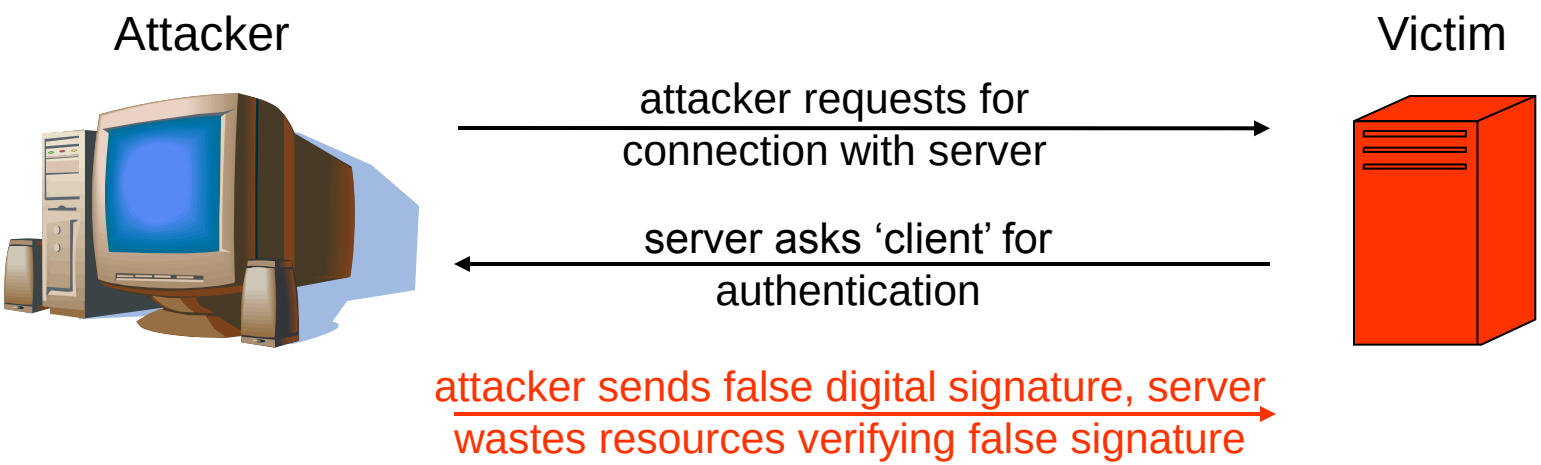
a.) Master-Slave-Victim



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!!!

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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

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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.

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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