Introduction to Computer Security

(ECE 458)

Vijay Ganesh

Winter 2013

ECE 458, Winter 2013 — Introduction to Computer Security

Prereq for course:	Linux "capability."
When & where:	Lectures: Tue & Thu 1:00 – 2:20 PM, QNC-2502. (No tutorials.)
Who:	Vijay Ganesh. Office: DC-2530 TA (Primarily Systems): Frank Imeson. Office: E5-4119 TA (Primarily Theory): Alireza Sharifi. Office: DC-3576 TA (Both): Carlos Moreno. Office: EIT-4103
What to call me:	"Vijay," "Prof. Vijay Ganesh."
Course materials:	`http://learn.uwaterloo.ca`
Email:	vganesh@uwaterloo.ca fcimeson@gmail.com a9sharifi@uwaterloo.ca cmoreno@uwaterloo.ca
Office hours:	Me: TTh 2:30 – 3:30 PM, or by appointment Frank Imeson: Fri 1:00 – 2:00 PM, or by appointment Alireza Sharifi: Mon 9 – 10 AM, or by appointment Carlos Moreno: Wed 3:30 – 4:30 PM, or by appointment
Textbook:	None.
Recommended Book:	Introduction to Computer Security by Matt Bishop.
Marking:	Assignments: 20%, Mid-term: 10%, Project: 20%, Final: 50%.
Assignments:	Approx. every 2–3 weeks. Groups of 2.
Project:	2-person group. Submit proposal by 2nd week for approval. Only approved projects receive a grade. Project demo and 5-10 page report are a must to receive a grade.
How to form a group:	Indicate both names on your (joint) submission for Assignment 1. This is your 2-person group for the entire term.

Policies:	Lateness: No late submissions accepted.
	Academic integrity:
	`http://uwaterloo.ca/academicintegrity/`
	`http://uwaterloo.ca/academicintegrity/Turnitin/`
	Petition & Grievance:
	`http://secretariat.uwaterloo.ca/Policies/policy70.htm`
	Discipline:
	`http://secretariat.uwaterloo.ca/Policies/policy71.htm`
	Penalties:
	`http://secretariat.uwaterloo.ca/guidelines/penaltyguidelines.htm`
	Appeals:
	`http://secretariat.uwaterloo.ca/Policies/policy72.htm`
	Disability:
	`http://www.studentservices.uwaterloo.ca/disabilities/`

This course is about:	Common sense, hands-on work, basic reasoning.

Online Resources, Books, Notes,...

- Books
  - Introduction to Computer Security by Matt Bishop
  - Computer Security: Art and Science by Matt Bishop
  - Hacking: The Art of Exploitation by Jon Erickson
- Notes and slides
  - Course notes/lectures by Prof. Mahesh Tripunitara (Waterloo)
  - Course notes/lectures by Prof. Dan Boneh (Stanford)
  - Course notes/lectures by Prof. John Mitchell (Stanford)
  - Course notes/lectures by Prof. Bill Young (UT, Austin)
  - Course notes/lectures by Prof. Matt Bishop (UC, Davis)
- Websites
  - Website by Dan Bernstein (http://cr.yp.to/djb.html)
  - Website by Schneier (http://www.schneier.com/)

Goals of this Course (Syllabus)

- Theory
  - Foundational concepts in security (e.g., confidentiality, integrity,...)
  - Security policies (e.g., access control,...)
  - Basic crypto (e.g., public key cryptography, key management,...)
  - Principles of secure design (e.g., least privilege, fail-safe,...)

- Practice
  - Authentication (e.g., password schemes)
  - Forms of attack, Malware (e.g., viruses, worms, buffer overflow attacks)
  - Mechanisms to prevent/detect/recover from attacks (e.g., layout randomization)
  - Software engineering tools to improve security (e.g., vulnerability and information flow analysis, pen testing, language design)

Topics covered in this Lecture

- Basic components of computer security
  - Confidentiality
  - Integrity
  - Availability
- Classes of threats
  - Disclosure
  - Deception
  - Disruption
  - Usurpation
- Policy vs. mechanism
  - Security Policies, e.g., access control
  - Mechanism to implement the policy
- Goals of security
  - Prevention
  - Detection
  - Recovery
- Trust and assumptions

What is Security? Why is it Important?

- What is computer security?
  - Often hard to define a field, esp. an evolving one
  - Techniques and mechanisms to "protect" systems and data from "threats"
  - Techniques to prevent, detect and recover from "threats" and "attacks"
  - Requires understanding of threat models, policies, trust, assumptions, properties
- Motivation to study security
  - National defense
  - Espionage by corporations and nations
  - Increasing societal reliance on computers
  - Financial transactions are primarily electronic
  - Privacy issues related to health/financial records
  - Technically challenging (both theory and practice)

Why is Security Hard?

- Thinking through all possible threat scenarios is difficult
  - Future-proofing a system is hard
  - Information systems are heterogenous, target-rich
  - Difficult to impose a uniform security policy
- Security often comes with a price, requiring trade-offs
  - Balancing security with system usability
  - Balancing security with system efficiency
  - Designing, implementing and deploying security features is costly
- Security ultimately is about risk management
  - Risk assessment (what are the threats, how much would they cost?)
  - How much are you willing to pay
  - Continuous re-assessment

Basic Components of Security (CIA)

- Confidentiality

  Concealment of information or resources

- Integrity

  Trustworthiness of data or resources (provenance)

- Availability

  Ability to use information or resource by "authorized" parties only

- Authentication

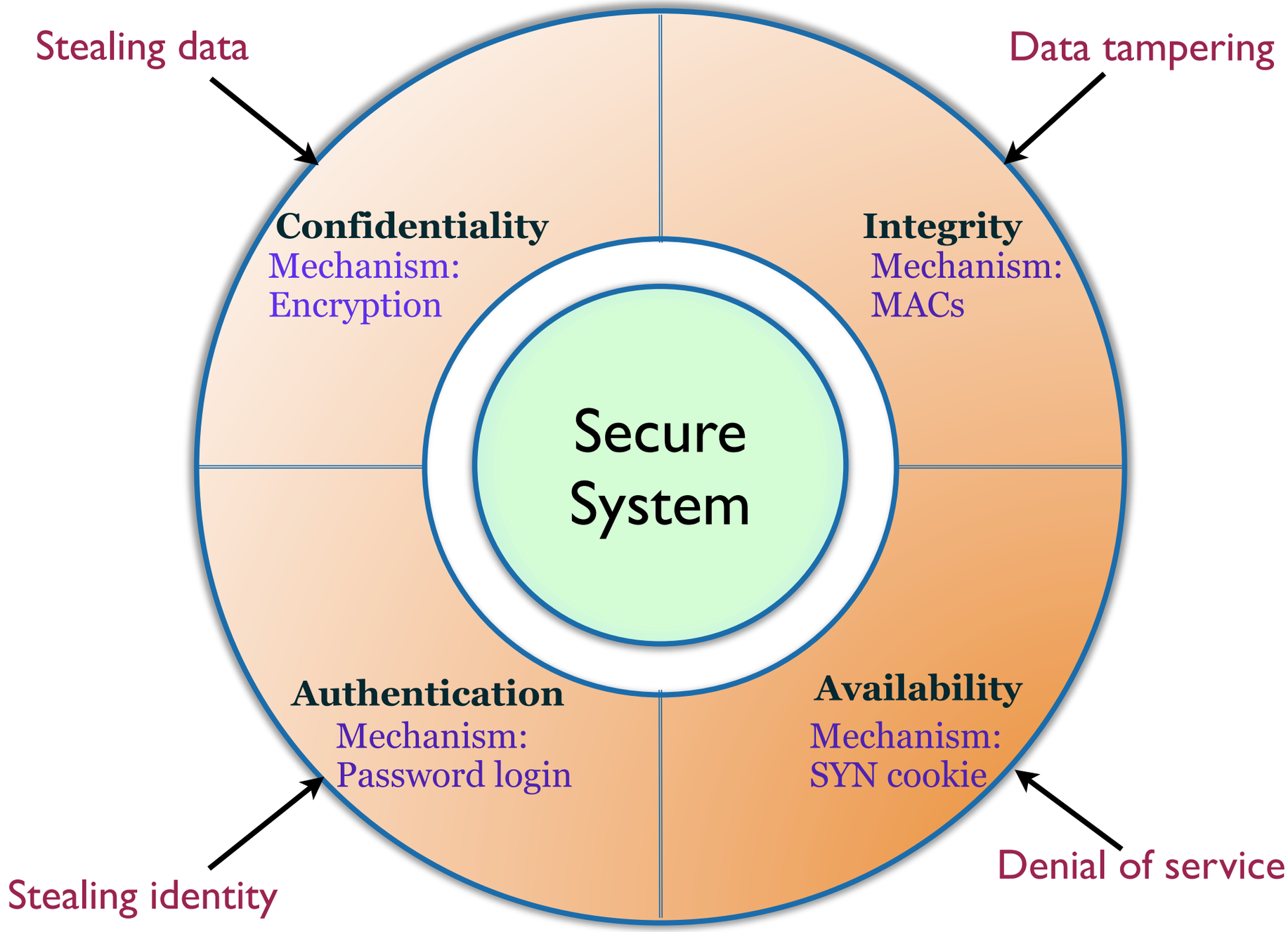
  Mechanisms to establish identity

- Non-repudiation

  Non-deniability of actions

What is Computer Security?

Prevent, Detect and Recover



Wait, what about...?

- Cryptography
- Digital signatures
- Access control
- Firewalls

- Authentication through passwords
- Digital certificates,...

These are mechanisms for providing confidentiality, integrity, availability, authentication,....

Confidentiality

- Concealment of information or resources
  - System makes it infeasible for unauthorized parties to "learn" concealed data or "access" resources
- Mechanisms to enforce confidentiality
  - Access control mechanisms support confidentiality
  - Encryption of data (decryption feasible only if key is available)
  - Data maybe in the clear, but resource requires authentication
  - Sometime even the existence of data (or occurrence of event) needs concealing
  - "Need to know" principle

Integrity

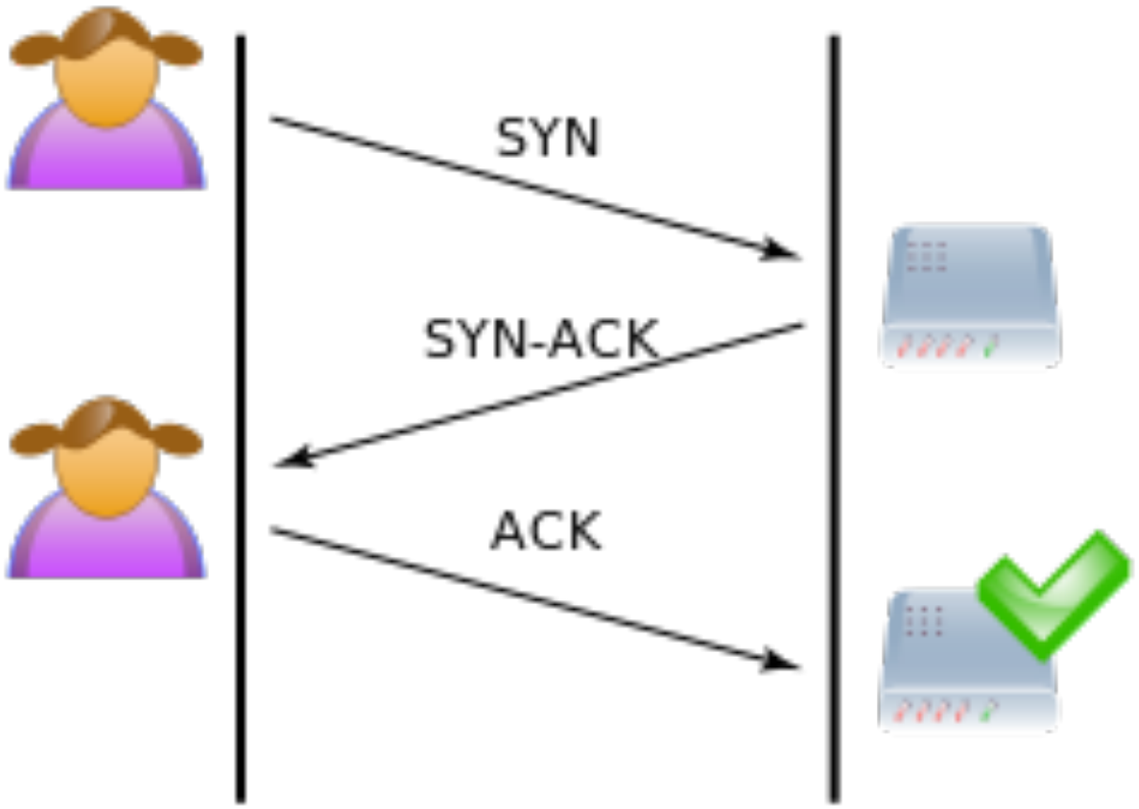
- Trustworthiness of data or resources
  - System prevents improper or unauthorized change to data
  - Data integrity: Data has not been "tampered" with
  - Origin Integrity: The source of the data is "verifiable"
- Mechanisms to enforce integrity
  - Prevention mechanisms
    - Block unauthorized attempts to change data (e.g., password protection)
    - Block attempts to change data in unauthorized ways (e.g., change policy)
  - Detection mechanisms
    - Detect unauthorized attempts to change data (e.g., MACs)
    - Detect attempts to change data in unauthorized ways (e.g.,MACs)

Availability

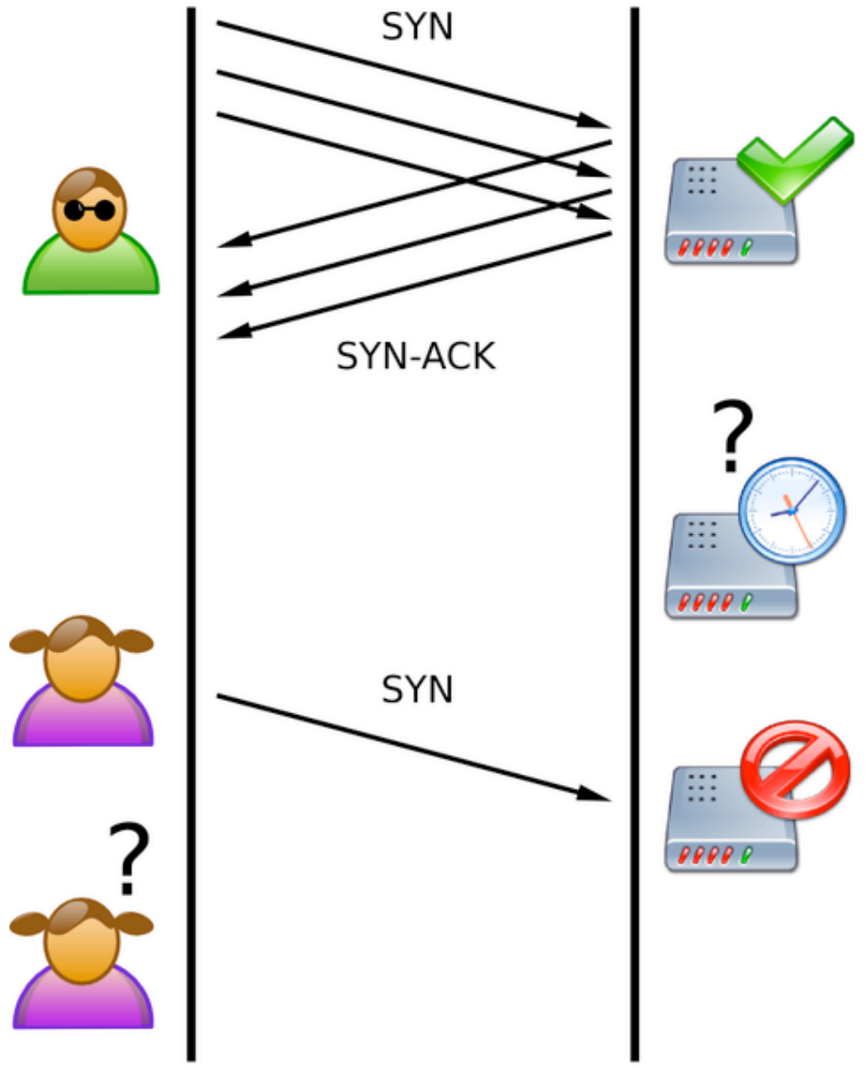
- Ability to use the information or resource desired
  - System ensures availability of information or resource
  - Attacker may attempt denial-of-service (DOS)
  - Attacker may exploit hidden assumptions to force DOS
- Mechanisms to ensure availability
  - Force attacker to pay a price for every DOS attack attempt (e.g., use of SYN cookies to protect against simple DOS attack)
  - Detection mechanisms: statistical models of normal behavior
- Hard to detect/prevent DOS attacks(esp. distributed ones)

SYN Flooding DOS Attack

Attack on Availability



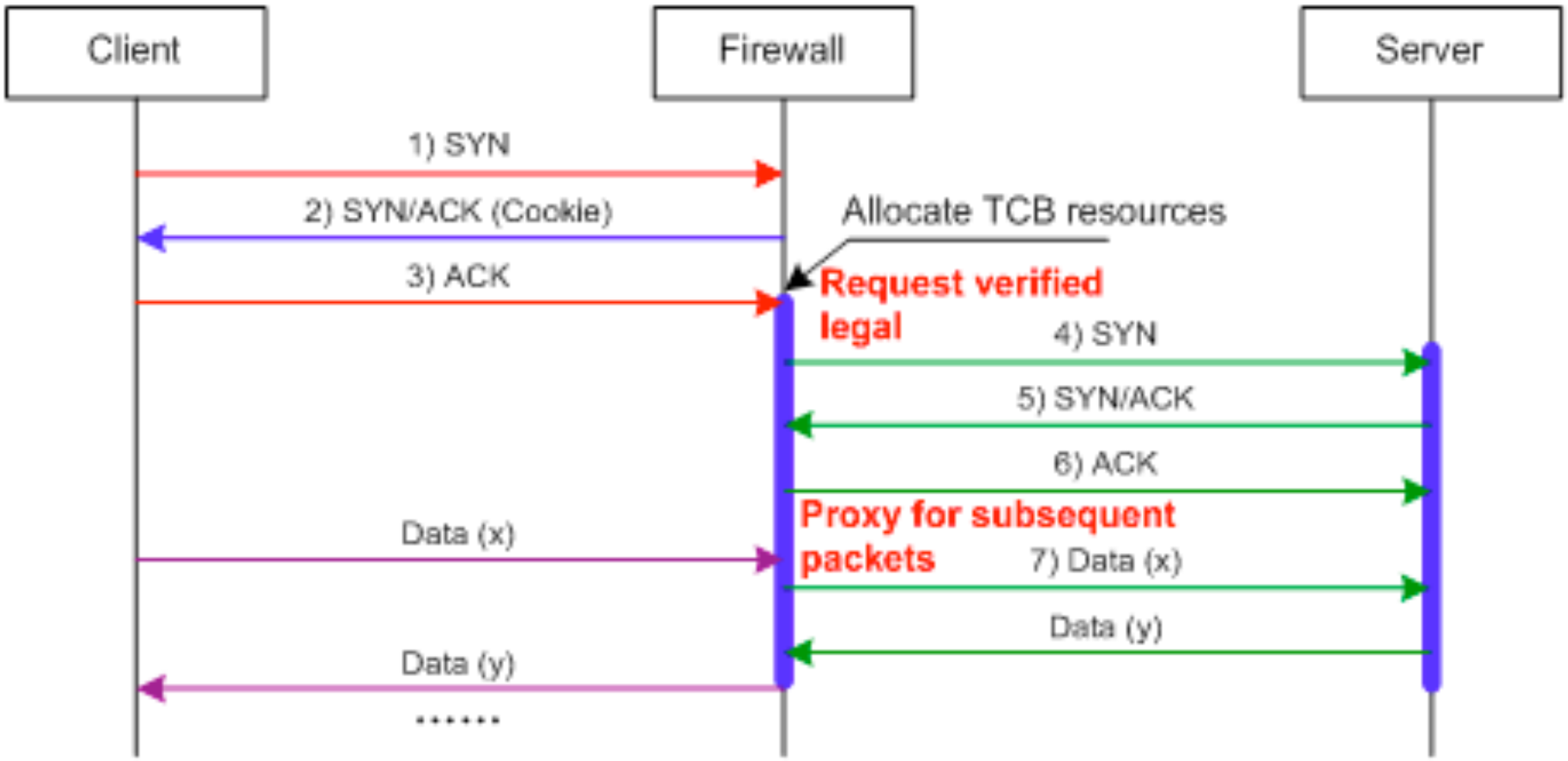
Normal TCP Operation



SYN Flooding Attack

SYN Flooding DOS Attack

SYN Cookies to the Rescue



Original idea: Dan Bernstein (http://cr.yp.to/djb.html)
Picture source: http://www.h3c.com

Authentication and Non-repudiation

- Authentication: Mechanism to establish identity
  - Password-based login implemented using cryptographic hash-functions
  - Collision-resistant and pre-image attack-resistant
  - MD5, SHA256,...
- Non-repudiation: Non-deniability of actions
  - Always ask for a receipt (proof of service provided)
  - Digital signatures (sender cannot deny sending message)

Threats

- A threat is a potential "violation" of security
- Actions leading to violations are called "attacks"
- Confidentiality, Integrity, Availability (CIA) counter threats
- Types of threats
  - Disclosure: unauthorized access to information (e.g., Stalin knew of the Bomb)
  - Deception: acceptance of false data (e.g., Afghan man pretending to be negotiator and deceiving the CIA)
  - Disruption: interruption of correct system operation (e.g., DOS attacks, Stuxnet)
  - Usurpation: unauthorized control of system (e.g., Botnets)

Snooping (Disclosure threat)

- Attacker is listening in, recording, monitoring the network
- Governments do this all the time
- How to protect against such a threat?

Snooping (Disclosure threat)

- Attacker is listening in, recording, monitoring the network
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- How to protect against such a threat?
  - Confidentiality services to rescue
  - Encryption
  - Need-to-know principle

Unauthorized Data Modification

- Can result in a variety of threats
  - Deception
  - Disruption
  - Usurpation
- Examples
  - Use buffer overflow to stack smash resulting in malicious code execution
  - Man in the middle attack
  - Privilege escalation in Web browsers due to software errors

Policy and Mechanism

- Policy
  - An unambiguous statement of what is, and is not, allowed
  - Security is very context-dependent
  - A policy, therefore, helps pin down what security means in a specific context
  - Policy may focus on one or more of a system's security components (CIAA)

- Mechanism
  - A procedure or tool to enforce a security policy
  - E.g., password-based login is a mechanism to implement access control policy

Access Control Matrix

- One of the earliest forms of access-control policies
- Implemented using access-control lists
- OS checks ACL before granting the subject permission

	Resource1 (File)	Resource2	Resource3
Alice	R,W	R	No access (N)
Bob	R,W,D	R,W	R
Carol	N	N	R

Trust and Assumptions

- Assumptions
  - Assuming crypto systems are unbreakable can be dangerous
  - Crypto guarantees can be side-stepped by stepping outside the crypto model
  - Side-channel attacks
  - Attacker may learn key by analyzing power consumption or cache behavior
- Trust
  - Very hard to quantify
  - Processors are manufactured in a variety of nations
  - How do you know that the computer manufacturer didn't put some backdoor?
  - Read "Reflections on Trusting Trust" paper by Ken Thompson
    - "You cannot trust code you didn't create yourself"

Design and Verification

- Principles of Secure Design
  - Principle of least privilege (e.g., user gets only essential privileges)
  - Principle of privilege separation (e.g., programs are split into two and granted separate privileges)
  - Principle of fail-safe defaults (e.g., access to resources only through explicit authority)
- Verification
  - PenetrationTesting
  - Formal methods (e.g., model-checking)
  - Information-flow analysis

Putting it all Together

Computer Security: Prevent, Detect and Recover