CS101

Network Thinking

Responsible Computing

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Outline

- What is network thinking?
- Network terms
- Connectivity
  - Naming
  - Topology
- Protocol stack
  - The Web over TCP/IP stack
  - Web programming
- Network laws
  - Performance metrics
  - Network effect
- Responsible computing

These slides acknowledge sources for additional data not cited in the textbook

6. What is responsible computing?

- Ideas and practices to design and use computing products and services responsibly
  - Cybersecurity issues
  - Privacy awareness
  - Professional norms

- Why bother?
- Computing has beneficial and harmful impact to society

6.1 Cybersecurity issues

- The global Internet is under constant attacks
- Cause harm to society

- Example study
  - McAfee (2020): The Hidden Costs of Cybercrime
    - Cybercrime costed companies worldwide US$1 trillion
    - > 1% of global GDP
    - Was about US$500 billion in 2016

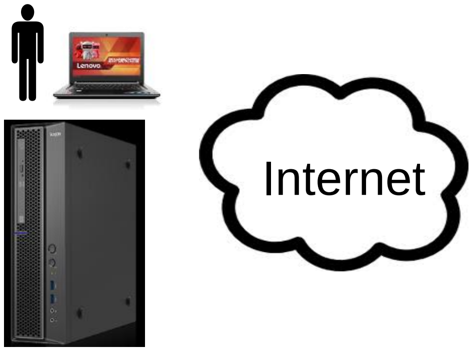
- Compare these to the worldwide computing market
  - The global ICT market: US$3.4 trillion in 2016
  - The global digital economy: US$11.5~24 trillion in 2016

Cybersecurity issues

- Cybersecurity problems involve hardware, software and people
  - Not only software such as computer viruses
- Cyber attack types
  - Malware: malicious software enabling an attacker to damage or gain unauthorized access to a computer
    - Computer viruses, Trojan horses and spyware
  - An attack does not have to be in a software form
    - Hardware exploitation
      - Meltdown: exploiting “out-of-order execution”, a feature of processor hardware
        - Enabling an attacker to read privileged information passwords
  - An attack does not have to install anything on the targeted system
    - Denial-of-service (DoS) attacks, distributed denial-of-service (DDoS) attack
    - Spams: unwanted emails
    - *Phishing*: phishing websites or phishing emails

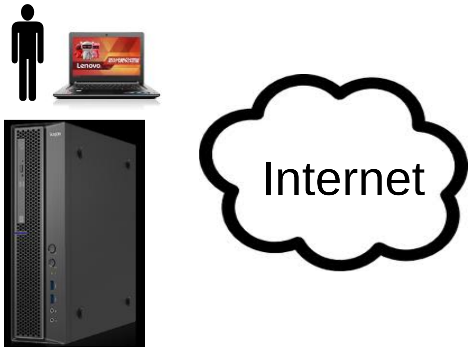
Counter measures

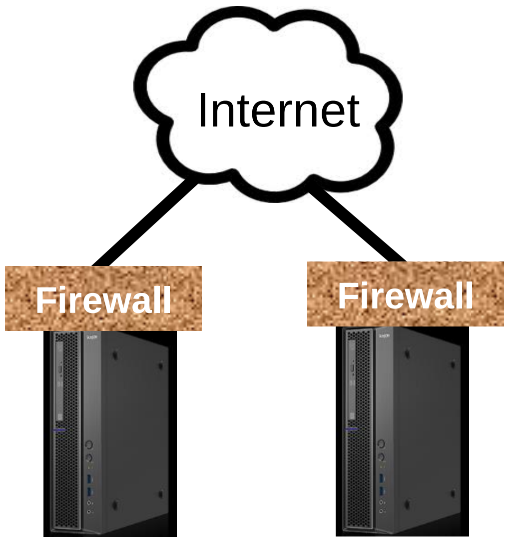
- Physical isolation: critical computing systems disconnected from the Internet



Counter measures

- Physical isolation: core computing systems disconnected from the Internet
- Firewalls: block or filter out undesirable messages





Counter measures

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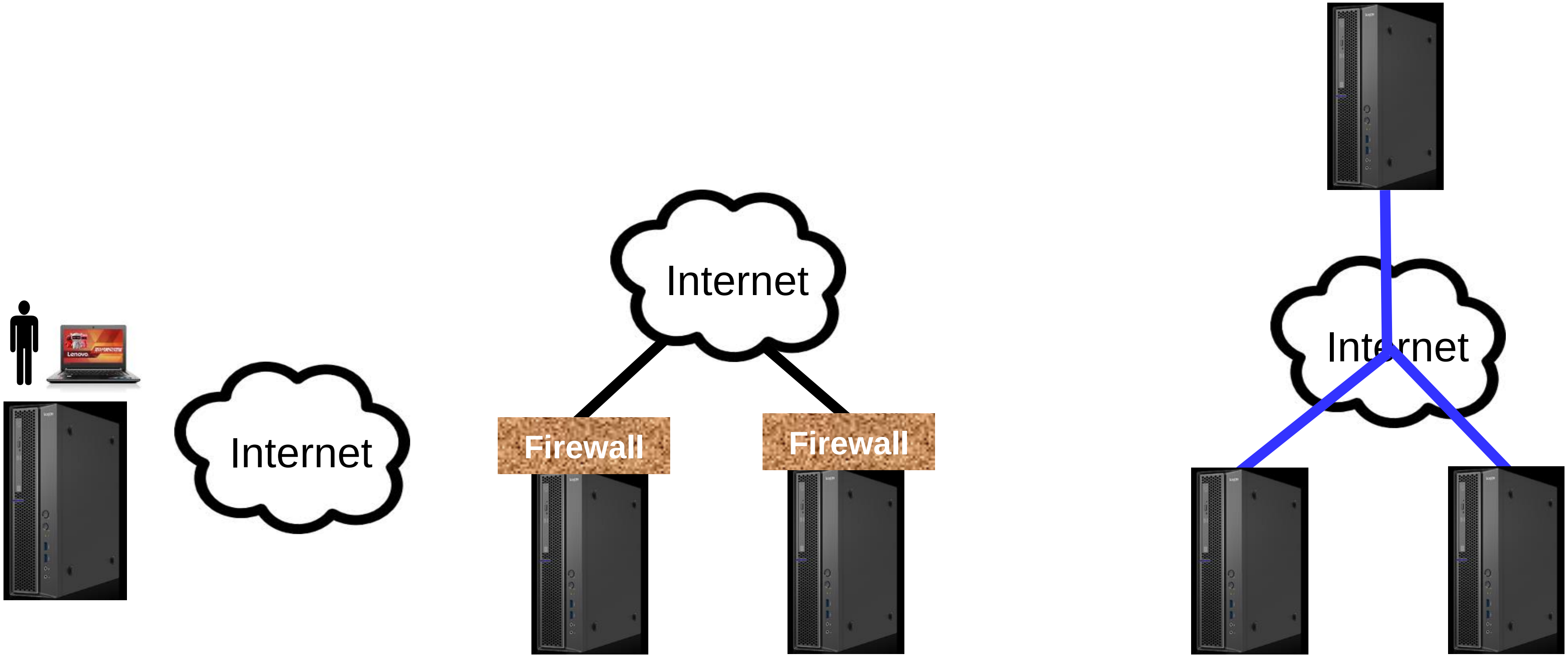
- Virtual private networks (VPNs)



Counter measures

- Physical isolation: core computing systems disconnected from the Internet
- Firewalls: block or filter out undesirable messages
- Virtual private networks (VPNs)

- Antivirus software: detect and kill computer viruses

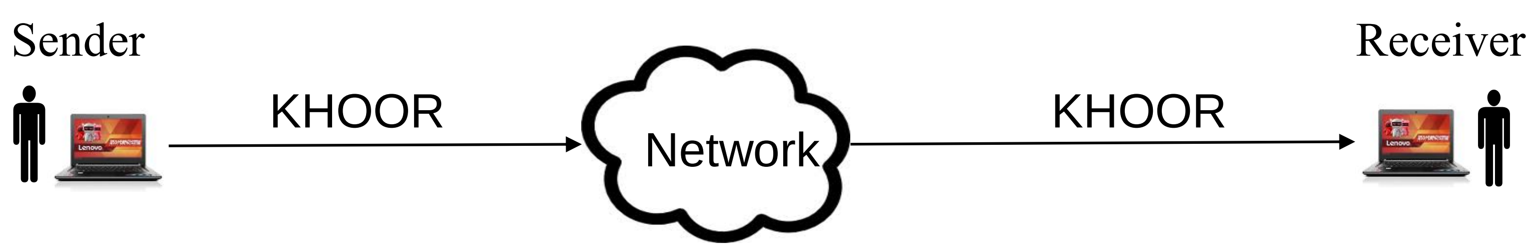
- Cryptography
  - Secure message communication in the presence of adversaries
  - Encryption: plaintext → ciphertext HELLO → KHOOR
  - Decryption: ciphertext → plaintext KHOOR → HELLO

Symmetric-key encryption: Caesar cipher

- Sender and receiver share a key (3 in this example)
  - Only a single key is used by both parties, thus symmetric
- Sender encrypts the plaintext (string of capital letters)
  - By shifting each letter L 3 positions down the alphabet, i.e., ASCII(L)+3
  - E.g., ‘**H**’+3 = 72+3 = 75 = ‘K’

  and sends the ciphertext over the network to the receiver
- Receiver decrypts the ciphertext
  - By shifting each letter L up 3 positions, i.e., ASCII(L)-3
  - E.g., ‘K’-3 = 75-3 = 72 = ‘**H**’

Alphabet
A
B
C
D
E
F
G
H
I
J
K
…



HELLO → KHOOR
Shift **3** positions down
Encryption

KHOOR → **H**ELLO
Shift **3** positions up
Decryption

Public-key encryption: the RSA method

- Receiver has two keys
  - Public key $\boldsymbol{K_P}$: known to everybody, including the eavesdropper
    - Used by the sender to encrypt plaintext into ciphertext
  - Private key $\boldsymbol{K_S}$: known only to receiver; also called **secrete key**
    - Used by the receiver to decrypt ciphertext into plaintext
- Process of securely communicating a plaintext decimal number **920**
  - Receiver makes the magic assumption: *n*=2773,*d*=157,*e*=17
  - Sender
    - Knows the public key $\boldsymbol{K_P} = (e, n) = (17{,}2773)$
    - Uses encryption algorithm $C = M^e \bmod n$ to obtain ciphertext *C* from plaintext *M*

      $$C = M^e \bmod n = \mathbf{920}^{17} \bmod 2773 = 948 = 0948$$
    - Sends ciphertext 0948 over the open Internet to receiver
  - Receiver
    - Knows both $\boldsymbol{K_P} = (e, n) = (17{,}2773)$ and $\boldsymbol{K_S} = (d, n) = (157{,}2773)$
    - Uses decryption algorithm $M = C^d \bmod n$ to obtain plaintext *M* from ciphertext *C*

      $$M = C^d \bmod n = 948^{157} \bmod 2773 = \mathbf{920}$$

Securely communicating a message

- The plaintext message
    - A 20-character message “ITS ALL GREEK TO ME ”
- Process
    - Sender
        - Encodes the text message by: space=00, A=01, B=02, …, Z=26 to obtain a 40-digit number
            - 0920190001121200071805051100201500130500
        - Divides into 4-digit groups
            - 0920 1900 0112 1200 0718 0505 1100 2015 0013 0500
        - Encrypts plaintext number sequence into ciphertext number sequence
            - 0948 2342 1084 1444 2663 2390 0778 0774 0219 1655
        - Sends this ciphertext number sequence to receiver
    - Receiver
        - Decrypts ciphertext number sequence into plaintext number sequence
            - 0920 1900 0112 1200 0718 0505 1100 2015 0013 0500
        - Decodes number sequence into character string
            - “ITS ALL GREEK TO ME ”

How are the magic numbers determined?

- Magic numbers: n = 2773, d = 157, e = 17

- Process by receiver
  - Randomly chooses two large primes p and q, and sets $n = p \times q$
    - $p = 47,\ q = 59,\ n = p \times q = 47 \times 59 = 2773$
  - Computes the Euler number $(p-1) \times (q-1)$
    - $(p-1) \times (q-1) = 46 \times 58 = 2668$
  - Randomly chooses a large integer d such that $\mathrm{GCD}(d, 2668) = 1$
    - Set $d = 157$ which satisfies $\mathrm{GCD}(157, 2668) = 1$
    - Complete private key information: $K_S = (d, n) = (157, 2773)$
  - Finds value e satisfying $(d \times e) \bmod 2668 = 1$
    - $e = 17$ which satisfies $(157 \times 17) \bmod 2668 = 1$
    - Complete public key information: $K_S = (e, n) = (17, 2773)$

RSA allows eavesdropper to know a lot

- A lot of information is open to the world to know
  - The encryption algorithm $C = M^e \bmod n$
  - The decryption algorithm $M = C^d \bmod n$
  - The public key $K_P = (e, n) = (17, 2773)$
  - The character converting scheme: space=00, A=01, B=02, …, Z=26
  - The ciphertext number sequence
    - 0948 2342 1084 1444 2663 2390 0778 0774 0219 1655
- Yet, the eavesdropper cannot decipher the message
  - He lacks the private key $K_P = (d, n) = (157, 2773)$
  - He does not know $d = 157$, which is the solution to $\text{GCD}(d, 2668) = 1$
  - He does not know 2668, which is the Euler number $(p-1) \times (q-1)$
  - He knows $n = p \times q$, but does not know the prime numbers $p,\ q$
- Can the eavesdropper find an efficient algorithm
  - Which recovers prime numbers $p,\ q$?
- Not likely

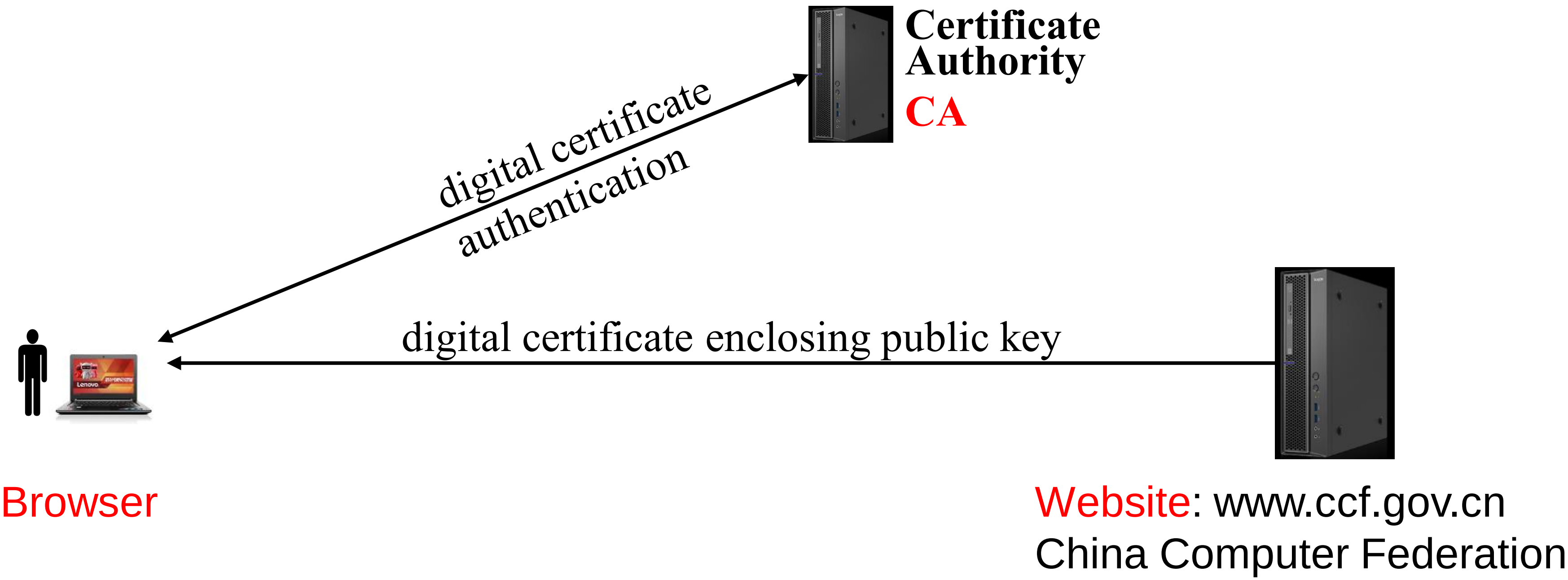
The prime factorization problem

- Given a large natural number n, find the prime numbers $p,\ q$ such that $n = p \times q$
  - Given $n = 2773$, find $p = 47,\ q = 59$, such that $p \times q = 2773$
- This problem has no known efficient algorithm
- RSA relies on this fact

- As of year 2020, the largest RSA integer factored is RSA-250, which has 250 decimal digits
  - A French-US team accomplished the prime factorization task utilizing a network of parallel computers in Europe and the USA
  - The total computing resources used are roughly 2700 core-years
  - At least hundreds of years of computing on a student's laptop

HTTPS: RSA application

- HTTPS = HTTP + Transport Layer Security (TLS)
  - For secure communication between a browser and a website
  - Use symmetric-key and public-key encryption techniques
    - For the long term, use public-key encryption
    - For the short term, use onetime symmetric-key encryption
      - E.g., a HTTP GET session



6.2 Privacy issues

- Privacy: keeping a user's identity and personally identifiable information (PII) *private*.
- Personal information
  - Any information relates to a natural person's identity
  - Includes personally identifiable information (PII)
  - Does not include anonymized personal information
- Personal information is broad
  - Such as personal names, ID numbers, personal photos or videos, website clicks records, voice signals, financial records, medical data
- Personal data can be revealed by technology
  - Utilizing metadata, data mining, AI

Sources of further information

- In the computing field
  - *IEEE Security and Privacy* is a professional magazine exploring security and privacy issues
  - Tim Berners-Lee’s Solid initiative

- In the legal field
  - GDPR: European Union enacted a law framework, called *General Data Protection Regulation*
    - Went into effect in 2018
  - PIPA: the National People’s Congress of the People’s Republic of China published a request for comments of a *Personal Information Protection Act*
    - To become effective in November 2021

Basic principles of the laws

- Facilitate protection as well as use of personal information
- A person has basic rights to his/her personal information, such as:
    - Right to permit a third party to collect and use personal data
    - Right to timely rectification of personal data
    - Right to be forgotten
    - Right to port one's personal data to another website
- These rights are protected by law, even when a piece of personal data is not owned by the person
    - A person's cellphone number is protected, even though the number belongs to the telecom company, and the person only "rents" it
- Another person or institution can collect, store, process, and otherwise use a person's data in a legal and fair way
    - PIPA used 合法、正当、必要

6.3 Professional norms

- ACM code of conduct: seven principles
  - Contribute to society and to human well-being, acknowledging that all people are stakeholders in computing.
  - Avoid harm.
  - Be honest and trustworthy.
  - Be fair and take action not to discriminate.
  - Respect the work required to produce new ideas, inventions, creative works, and computing artifacts.
  - Respect privacy.
  - Honor confidentiality.

https://www.acm.org/code-of-ethics

Form your own thoughtful judgement

- Understand the ACM code of conduct
  - You don’t have to agree to it completely
    - The ACM code itself is evolving
  - But should try to understand what it says

- Apply it to the three examples in textbook, and form your own thoughtful judgement
  - Free flow versus professionally sharing of scientific data
  - Full disclosure versus responsible disclosure
  - The historical case of the Morris worm