Lecture 20: Cryptography, continued

- **some history**
  - Caesar cipher, rot13
  - substitution ciphers, etc.
  - Enigma (Turing)

- **modern secret key cryptography**
  - DES, AES

- **public key cryptography**
  - RSA, digital signatures, cryptographic hashing

- **cryptography in practice**
  - e-commerce
  - Tor browser
  - Bitcoin, blockchain
  - politics

Properties of public/private keys

- **can't deduce the public key from the private, or vice versa**
- **can't find another encryption key that works with the decryption key**
- **keys are long enough that brute force search is infeasible**

- **nasty problems:**
  - if a key is lost, all messages and signatures are lost
  - if a key is compromised, all messages and signatures may be compromised
  - it's hard to revoke a key
  - it's hard to repudiate a key (and hard to distinguish that from revoking)

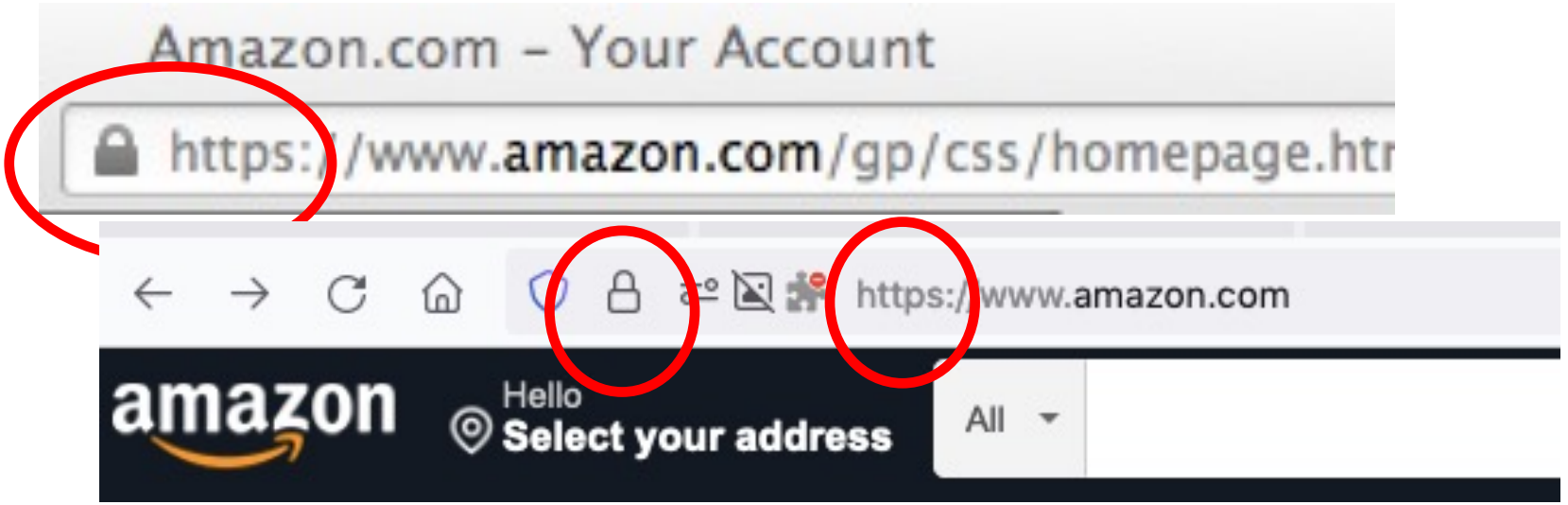
- **authentication**
  - how do you know who you are talking to? is that really Alice's public key?
  - public key infrastructure, web of trust, digital certificates

Encrypted transactions, online shopping

- **browser says "prove that you're really Amazon"**
- **Amazon says "here's my signed certificate from a CA"**
  - encrypted with the CA's private key
- **browser decrypts certificate with CA's public key**

- **browser generates a random key, encrypts it with Amazon's public key, sends it to Amazon**

- **browser and Amazon use AES to talk securely**



Government surveillance / Snowden revelations

- **2013: Edward Snowden, contractor at NSA, left his job**
- **flew to Hong Kong**
- **met several trusted journalists**
- **handed over thousands of highly classified documents**
- **that revealed global surveillance by NSA, and similar agencies in other countries**
- **with cooperation of telecomm and Internet companies**

- **went to Russia, given asylum**
  - citizenship in Sept 2022
- **called both traitor and hero in the US**

Virtual Private Networks (VPN)

- **a protected connection from your connection to a private network**
  - e.g., from your laptop at home to Princeton's network
  - as if you were on campus

- **created an encrypted "tunnel" from your computer to VPN host**

- **your traffic appears to come from / go to the VPN host, not you**
  - needs a VPN client on your computer
  - e.g., Palo Alto Netwokrs GlobalProtect at PU

- **you can still be tracked by cookies, fingerprinting, etc.**

- **you have to trust the VPN client and host**

- **it will be slower than a direct connection**

Tor: The Onion Router

- **anonymous routing through the Internet using TCP**
  - receiver can't determine the sender's address
- **sender creates a random path through a network of Tor relays**
  - path is changed frequently
- **each part of the path is encrypted**
  - separate encryption keys for each hop
- **each relay only knows who gave it data and who it sends data to**
  - no relay knows the whole path
- **messages are wrapped up with nested encryptions, one for each component of the path**
  - each relay removes one layer of encryption before passing it on
- **potentially vulnerable to some attacks**
  - traffic correlation at end points
  - exit nodes can be blocked or monitored

Bitcoin and other cryptocurrencies

- **how do we create a currency that is anonymous like cash**
  - can't tell who spends or receives it

- **is not dependent on any government**
  - i.e., not a "fiat currency" like $, £, €, ...

- **has the other desirable properties of money:**
  - portable, durable, divisible, recognizable, difficult to counterfeit

- **one solution:**

  use cryptography to control the creation and transfer of money, without relying on any central authority

Bitcoin

- **exists only in digital form: nothing physical like gold**
  - no central authority or control
  - anonymous ownership and transfer
  - value fluctuates wildly
- **how are bitcoins created?**
- **how is ownership validated & transferred without double spending?**

- **blockchain: a shared public ledger of *all* transactions**
- **a transaction transfers value from one wallet to another**
  - signed digitally by the sender
  - broadcast via peer to peer network so the block chain can be updated
- **"mining" confirms transactions by adding them to the blockchain**
  - competitive distributed consensus algorithm
  - takes work to confirm; new bitcoins are created as a reward
  - blocks are protected by cryptographic hashing; each new one depends on all previous ones

Blockchain

- **a distributed ledger of transactions stored as a sequence of data blocks**
- **the blocks are protected and linked by cryptographic hashing**
- **a block can't be changed without changing all blocks that precede it**
- **cryptocurrencies are the most frequent use, but not the only one**
  - Ethereum blockchain, ETH currency

Crypto politics

- **cryptographic techniques as weapons of war?**
  - (strong) cryptography was classified as "munitions" in USA
  - fell under International Traffic in Arms Regulations and follow-ons
- **export control laws prohibited export of cryptographic code**
  - though it was ok to export books and T-shirts with code
    and everyone else in the world had it anyway
  - changed during 2000, but there are still restrictions
- **does the government have the right / duty ...**
  - to control cryptographic algorithms and programs?
  - to require trapdoors, key escrow, or similar mechanisms?
  - to prevent reverse-engineering of cryptographic devices?
  - to prevent research in cryptographic techniques?
- **do corporations have the right ...**
  - to prevent publication of cryptographic techniques?
  - to prevent reverse-engineering of cryptographic devices?
- **how do we balance individual rights, property rights, & societal rights?**

Summary of crypto

- **secret/symmetric key algorithms: AES, ...**
  - key distribution problem: everyone has to have the key
- **public key algorithms: RSA, ...**
  - solves key distribution problem, but authentication is still important
  - also permits digital signatures
  - much slower than secret key, so used mainly for key exchange
- **security is entirely in the key**
  - “security by obscurity” does not work: bad guys know everything
  - brute force attacks work if keys are too short or easy
- **good cryptography is hard**
  - you can't invent your own methods
  - you can't trust “secret” or proprietary methods
- **people are the weak link**
  - complicated or awkward systems will be subverted, ignored or misused
  - social engineering attacks are effective

    ignorance, incompetence, misguided helpfulness
- **if all else fails, try bribery, burglary, blackmail, brutality**

Cryptography is important

- **it protects our privacy and security**
  - access to computers
  - email
  - online shopping, banking, taxes
  - electronic voting
  - ...

- **it can restrict our rights and freedoms**
  - digital rights management: limits on what we can do with music, movies, software, ...

- **it helps good guys and bad guys alike**