Computer Security

14r. Pre-exam 3 Review

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This covers highlights of the past
four lectures – *not* all the material

If any of this is really unclear to you,
it's an indication that you should spend some time
studying the material

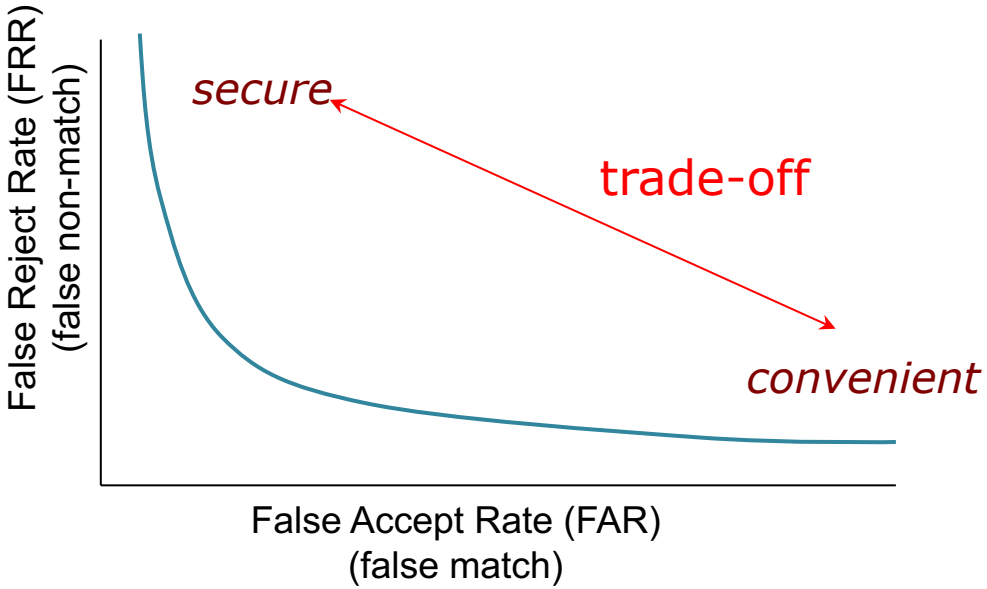
Biometrics

Biometric Authentication

- Identify a person based on physical or behavioral characteristics
  - Not ownership of keys or knowledge of passwords
- Unlike other forms of authentication
  - Biometrics relies on statistical pattern recognition
  - Comparing sampled biometric data with stored biometric data will almost never yield an exact match

ROC Curve

- False Accept Rate (FAR)
  - Non-matching pair of biometric data is *accepted* as a match
- False Reject Rate (FRR)
  - Matching pair of biometric data is *rejected* as a match
- ROC (Receiver Operator Characteristic) curve identifies the behavior of a biometric system
  - FAR vs. FRR

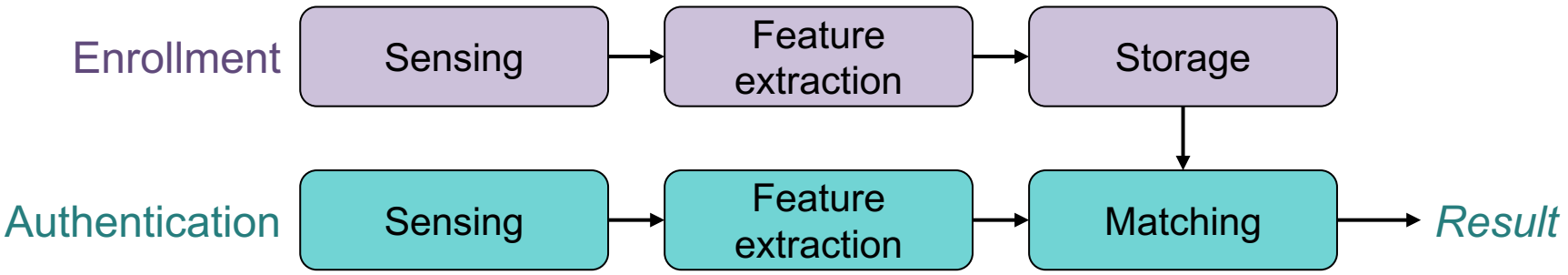


Robustness and Distinctiveness

- Robustness
  - Repeatable, not subject to large changes over time
  - Fingerprints & iris patterns are more robust than voice
- Distinctiveness
  - Differences in the biometric measurement among population
  - Fingerprints: typically 40-60 distinct features
  - Irises: typically >250 distinct features
  - Hand geometry: ~1 in 100 people may have a hand with measurements close to yours.

Authentication Process

1. Sensing
   - Capture the biometric data
2. Feature extraction
   - Extract the interesting (unique) parts of the data
3. Pattern matching
   - Compare the extracted data with stored samples
4. Decision
   - Decide whether the sensed data is close enough to the stored sample

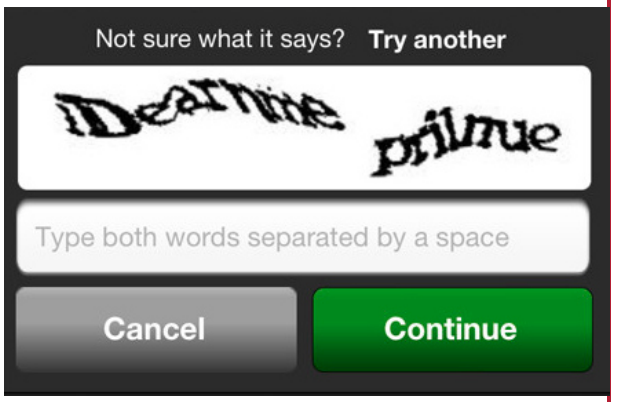


Security Problems

- Need a trusted and tamper-proof capture & authentication path
  - Sensor hardware → Feature extraction processing → Processing & Decision
- Need trusted storage for stored samples of data
- Biometric data cannot be compartmentalized
  - You cannot have different data for your Amazon & bank accounts
- Biometric data can be stolen
  - Photos (irises, fingerprints), lifting fingerprints
  - Once biometric data is compromised, it remains compromised
    - You cannot change your iris or finger

CAPTCHA

- *Not biometrics* – a technique for software to detect if it's dealing with a human being or a bot
- Present distorted text that is difficult for a computer to process but relatively easy for humans
- Alternate approach
  - Recognize pictures or parts of a scene
- Problem: OCR has improved to the point where computers can recognize sloppy text
- NoCAPTCHA RECAPTCHA
  - No puzzles!
  - Perform "risk analysis"
    - Check IP address of known bots
    - Check Google cookies for legiitimate users
    - Track mouse movements for randomness



Code Signing

- Challenge: distribute software and ensure that it is not modified during distribution or on the computer
- Solution
  - Use digital signatures, just like for messages
  - Publisher: Hash the software → encrypt the hash with your private key
  - User: Hash the software → validate the hash using the publisher's public key
- Publisher's public keys are distributed as X.509 digital certificates
- Sign page-size blocks of software
  - Operating system's demand paging does not load the whole program at once, just individual pages when they are needed
  - OS can verify a page as it is loaded

Network security

Data link layer

- MAC Attacks – CAM overflow
  - An Ethernet switch builds up a switch table in content-addressable memory
  - Table identifies source ethernet MAC addresses with the switch port
  - If you send spoofed random source addresses, you will overflow the table
    - The switch will then broadcast all traffic onto all ports
- VLAN Hopping
  - A computer can spoof itself to appear as an ethernet switch with a trunk connection to another switch
  - It will receive traffic for all VLANs (Virtual Local Area Networks) and can see all of it rather than just the traffic for one VLAN

Data link layer

- ARP cache poisoning
  - Address Resolution Protocol (ARP): computer broadcasts a query asking if anyone knows the MAC address corresponding to a given IP address
  - Anyone can reply
  - If a malicious host responds with its MAC address, it will receive traffic for that IP address
- DHCP server spoofing
  - DHCP is used to configure devices on the network
  - Assigns IP address, subnet mask, router address, DNS server address
  - A malicious host can act as a DHCP server and provide bad data for routers or DNS servers to redirect traffic

Network (IP) & transport (TCP/UDP) layers

- No source address authentication – anyone can fake a source address
- UDP data– trivial to forge since there is no sequencing
- TCP data – harder: need to match sequence numbers
- TCP connection setup
  - Random starting sequence numbers make it hard to guess sequence #
  - SYN flooding attack:
    - Send TCP connection requests (SYN packets) with an unreachable source address
    - Receiver will allocate resources for the connection
    - Eventually will not be able to accept any more connections
  - Defense: SYN cookies
    - Do not allocate resources until the handshake is complete
    - Server computes the SYN-ACK sequence number by
      - hash(src_addr, dest_addr, src_port, dest_port, SECRET)
      - SECRET is just a random number that the server picked

Routing Protocols & DNS

- IP networks (autonomous systems) share routing information using BGP (Border Gateway Protocol)
  - TCP connection
  - Route announcements are not authenticated
  - Fake route announcements can cause routers throughout the Internet to redirect data to a different place
- DNS (Domain Name System)
  - Responsible for converting domain names to IP addresses
  - Responses can be intercepted & modified, providing the wrong address for a domain name

Firewalls & VPNs

Virtual Private Networks

- Key principle: Tunneling
  - Encapsulate an entire packet as payload in another packet that is routed over a public network
  - Receiver extracts the encapsulated packet and routes it onto its network
- **IPsec** – popular set of VPN protocols
  - Authentication Header (AH) protocol
    - Guarantees integrity & authenticity of IP packets
    - Adds a MAC for the contents of the entire IP packet
  - Encapsulating Security Payload (ESP)
    - Adds encryption of the entire payload (encapsulated packet)
  - IPsec uses
    - HMAC (hash-based MACs) for integrity
    - Symmetric cryptography for confidentiality
    - Kerberos, digital certificates, or pre-shared keys for authentication

Transport Layer Security (TLS)

- Goal: provide an authenticated, encrypted, and tamper-proof connection between two hosts that software can use in a manner similar to TCP sockets
- Designed with web security in mind
  - Mutual authentication is usually not needed
    - Client needs to identify the server but the server won't know all clients
    - Users may often log in from different systems, so certificate & key management may be troublesome
    - Rely on passwords after the secure channel is set up

SSL/TLS Principles

- Use symmetric cryptography to encrypt data
  - Keys generated uniquely at the start of each session
- Include a MAC with transmitted data to ensure message integrity
- Use public key cryptography & X.509 certificates for authentication
  - Optional – can authenticate 0, 1, or both parties
- Support different key exchange, encryption, integrity, & authentication protocols – negotiate what to use at the start of a session

Firewalls

Firewall (screening router)	1st generation packet filter that filters packets between networks. Blocks/accepts traffic based on IP addresses, ports, protocols
Stateful inspection firewall	Like a screening router but also takes into account TCP connection state and information from previous connections (e.g., related ports for TCP)
Application proxy	Gateway between two networks for a specific application. Prevents direct connections to the application from outside the network. Responsible for validating the protocol.
IDS/IPS	Can usually do what a stateful inspection firewall does + examine application-layer data for protocol attacks or malicious content
Host-based firewall	Typically screening router with per-application awareness. Sometimes includes anti-virus software for application-layer signature checking
Host-based IPS	Typically allows real-time blocking of remote hosts performing suspicious operations (port scanning, ssh logins)

Web Security

Same-origin Policy

- Web application security model: **same-origin policy**
- A browser permits scripts in one page to access data in a second page ***only if*** both pages have the same origin
- Origin = { URI scheme, hostname, port number }
- Same origin
  - http://www.poopybrain.com/419/test.html
  - http://www.poopybrain.com/index.html
- Different origin
  - https://www.poopybrain.com/index.html – different URI scheme (https)
  - http://www.poopybrain.com:8080/index.html – different port
  - http://poopybrain.com/index.html – different host

Ideas behind the same-origin policy

- Each origin has client-side resources
  - Cookies: simple way to implement state
    - Browser sends cookies associated with the origin
  - JavaScript namespace: functions & variables
  - DOM storage: key-value storage per origin
  - DOM tree: JavaScript version of the HTML structure
- Each frame gets the origin of its URL
- JavaScript code executes with the authority of its frame's origin
  - If cnn.com loads JavaScript from jQuery.com, the script runs with the authority of cnn.com
- Passive content (CSS files, images) has *no* authority
  - It doesn't (and shouldn't) contain executable code

Cross-Origin Resource Sharing (CORS)

- A page can contain content from multiple origins
  - Images, CSS, scripts, iframes, videos

- XMLHttpRequests from different origin are *not* permitted
  - **CORS** – allows servers to define allowable origins

  - Example, a server at `service.example.com` may respond with
    `Access-Control-Allow-Origin: http://www.example.com`

  - Stating that it will allow treating `www.example.com` as the same origin

Cross-Site Request Forgery (XSRF)

- A browser sends cookies for a site along with a request
- If an attacker gets a user to access a site
  … the user's cookies will be sent with that request
- If the cookies contain the user's identity or session state
  - The attacker can create actions on behalf of the user
- This attack works if the URL and cookies contain all necessary information to perform an action
- Planting the link
  - Forums or spam
    http://mybank.com/?action=transfer&amount=100000&to=attacker_account

Clickjacking

- Attacker overlays an image to trick a user to clicking a button or link
- User sees this

There's an invisible frame over the image with a clickable link. User clicks on a maliciously-placed link

- Defense
  - JavaScript in the legitimate code to check that it's the top layer
    window.self == window.top
  - Set `X-Frame-Options` to not allow frames from other domains

Input Sanitization

- As we saw in the past, using user input directly can be dangerous
- Malicious users can
  - Modify the content of JavaScript code
  - URLs
  - CSS definitions
- Cross-site scripting (XSS)
  - User-generated text presented as part of HTML (e.g., content from user forums)
  - This text can contain malicious JavaScript, HTML frames, etc.
  - Reflected XSS
    - URL contains malicious content that will be sent to the server and then back to the user (e.g., an invalid login message)
  - Persistent XSS
    - Website stores user input and presents it as part of HTML to other users

Mobile Device Security

Android Security

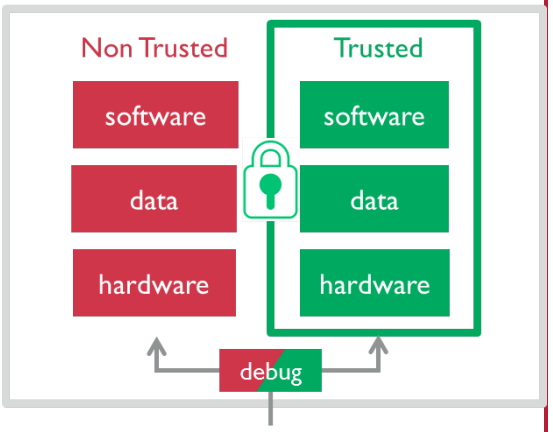
- App isolation
  - Apps run in a Dalvik virtual machine
  - Each app has its own Linux user ID
- App communication
  - Apps communicate with *intents*: messages that contain an action & data sent to some other component
- Permissions
  - Apps request permission to access resources at install time
  - OS maintains a whitelist of what an app is allowed to access
- File system encryption

iOS Security

- App isolation
  - App sandbox restricts access to other app's data & resources
- App communication
  - Inter-app communication only through iOS APIs
- Mandatory code signing
  - Must be signed using an Apple Developer certificate
- App data protection
  - Apps can use built-in hardware encryption
- File encryption
  - Each file is encrypted with a unique key

Hardware protection

- ARM TrustZone
  - Non-secure world cannot access secure resources directly
  - Main OS and apps run in the non-secure (non-trusted) world
  - If a key is stored in the secure world (trusted), even the OS cannot access it
- Processor executes in one world at any given time
- Each world has its own OS & applications
- Applications
  - Secure key management & key generation
  - Secure boot, digital rights management, secure payment
- Apple Secure Enclave: Apple's customized TrustZone
  - All cryptographic functions are handled in the secure enclave (secure world)



Content Protection, Watermarking, & Steganography

Content Protection and DRM

- Digital Rights Management (DRM)
  - Specify how content can be played and copied
  - Requires a trusted player (trusted software) that plays by these rules
- Digital Video Broadcasting
  - Encrypted content
  - Key (Encrypted Control Word) for the content changes every few minutes and is also broadcast
    - These ECW keys are encrypted with another key. This key is updated less frequently to each user & encrypted with the secret key in their smart card
- CableCARD
  - Secure device that stores keys and decrypts encrypted video streams if the user is authorized
  - Authorization info and keys are encrypted for the card and sent to the user

DVD and Blu-Ray

- Movie is encrypted with a symmetric media key
- The media key is encrypted lots of times, once for each device family
- Trusted player decrypts the media key for with its device key
- Both DVD and Blu-Ray content protection systems have been broken
  - You can get a lot of player keys and most (all) media keys

Steganography & Watermarking

- Steganography
  - Hide the contents of a message
  - Goal: transmit the hidden message to a receiver who knows what to look for
  - Examples
    - Null Cipher: Hide the message among other useless data (e.g., look at the first character of each word)
    - Chaffing & Winnowing:
      - Messages are sent in plaintext but only some messages are valid
      - Each message is signed but signatures for invalid messages are garbage
      - Only trusted receivers have the key to validate signatures
    - Images
      - Set least-significant bits
      - Hide a message in the frequency domain
- Watermarking
  - Goal: robust message that an intruder cannot remove
  - Not necessarily invisble

Watermarking

- Examples
  - Ultraviolet images on documents
  - Text with lines, words, or letters shifted based on bits to transmit
  - Bits added to pictures, audio, or video data (as with steganography)

The end