# Crypto with Passwords

Lecture 19

Q&A

# Passwords

- Password or passphrase: Low-entropy shared secret
  - Typical goal: client authenticating to server, without being tied to a device holding a cryptographic key. On authentication, set up a session key.
  - Also, often Mutual Authentication (if server/client can't/doesn't want to use certificates to verify server's authenticity)
- Cannot get "negligible" security error: password can be guessed with some significant probability
- Goal: allow only an online guessing (dictionary) attack. Prevent offline dictionary attacks.
  - Or if server compromised, still somewhat protect the passwords, by allowing only a slow offline dictionary attack

# Key from Password

- Common scenario: client only has a password rather than a key. Server has some information derived from client's password
- They will on-the-fly generate a session key from the password, and interact using it
  - Note: Client may not a priori know if the server is genuine
- Requires the key to be as good as random, up to the probability that the adversary can guess the password and interact with the server itself
  - Rate/number of attempts would be limited, so online dictionary attack would be OK
- Simple solution in the random oracle model: Key = H(passwd)
  - Note: Standards here often call H a "PRF" as not only collision resistance, but also pseudo randomness is important

# Key from Password

- Simple solution in the random oracle model: Key = H(passwd)
- But if the password server is compromised an attacker can launch an offline dictionary attack
  - Typically quite feasible to discover many passwords
  - Attacker may possess a "Rainbow Table" — precomputed hashes of a dictionary — and can quickly recover almost all the stored passwords
- Typical solutions
  - **Salting** prevents Rainbow Table attacks: Key = H(passwd,salt) where salt is a long random string (sent to the client)
  - To make offline dictionary attack harder, use (moderately) hard hash functions

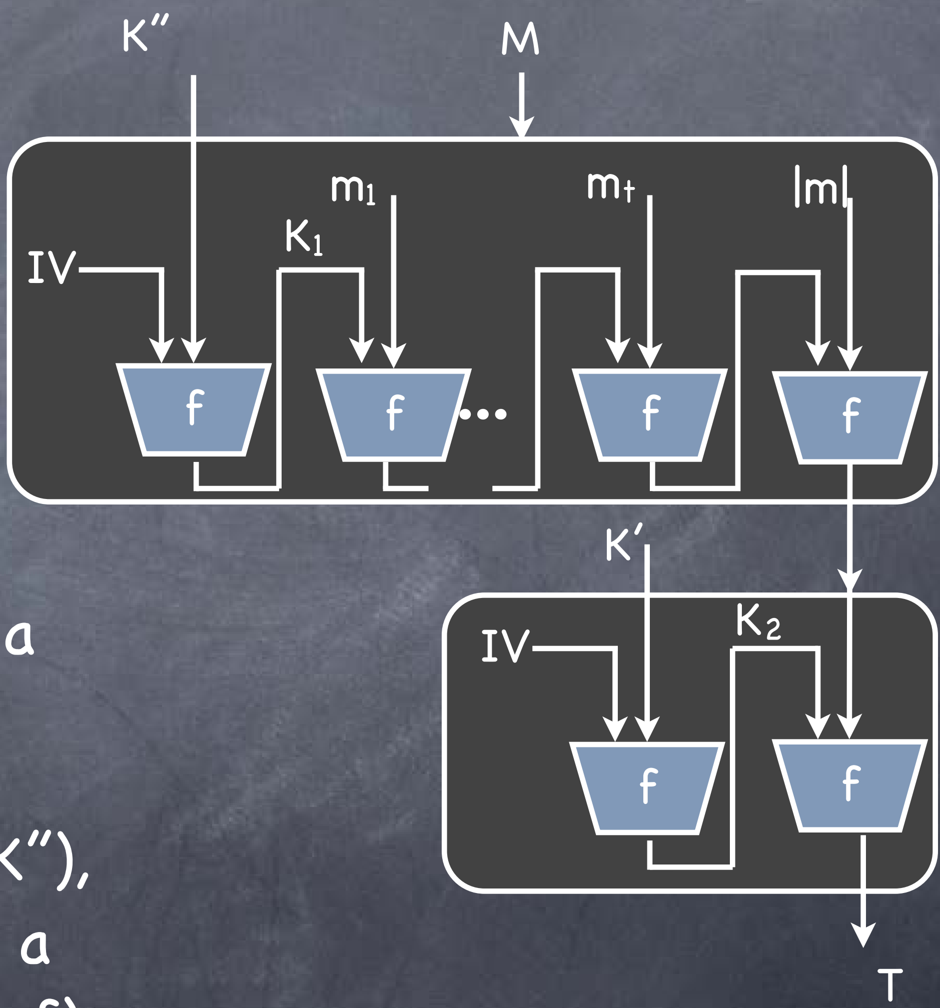
# Key from Password

- Idea: computing $H(\cdot)$ should be moderately hard, so that the attacker is slowed down
- Iterated hash functions
  - e.g., PBKDF2 in RSA PKCS #5 (version 2):
    H(IV,msg) treated like a PRF, with IV being a key.
    Iterate as $U_1$ = H(Passwd,Salt), $U_{i+1}$ = H(Passwd,$U_i$).
    Output length extended using "counter mode".
- WPA2: between an Authenticator (server) and a Supplicant (client), where they share a "Pre-Shared Key":
  PSK = PBKDF2(hash = HMAC-SHA1, #iterations = 4096,
  msg = Passwd, salt = SSID, output length = 256 )
  "Transient Key" derived from PSK, nonces exchanged, and mac addresses. Only nonces are exchanged between server & client.

RECALL

# HMAC

- HMAC: Hash-based MAC
- Essentially built from a compression function f
  - If keys $K_1$, $K_2$ independent (called NMAC), then secure MAC if: f is a fixed input-length MAC & the Merkle-Damgård iterated-hash is a weak-CRHF
  - In HMAC ($K_1$,$K_2$) derived from (K′,K″), in turn heuristically derived from a single key K. If f is a (weak kind of) PRF $K_1$, $K_2$ can be considered independent



# Key from Password

- While iterated hashing slows down attack in software, much faster custom hardware (a.k.a ASIC) is <u>not too expensive</u>
  - Solution (on going research): Memory Hard Functions
    - Fast memory is still very expensive
    - So try to make the function <u>require</u> large amounts of memory.

# Key from Password

- No forward secrecy in WPA2!
- If password is revealed past sessions can be decrypted
  - Transient key is derived from password and publicly known values (nonces exchanged)
  - Solution: Use keys from password only for authentication and use key exchange to derive encryption keys
  - Password-Authenticated Key Exchange (PAKE)

# PAKE

- Password-Authenticated Key Exchange
  - Agree on a secret symmetric key, over a network
  - Client has a password, and server has related information
- Some considerations
  - A session is compromised if the session key is not pseudorandom to the adversary
  - Adversary can interact with the server, or with the client, or with both, concurrently in multiple sessions using the same password
  - Adversary may learn a session key in one session, but that shouldn't compromise the keys in other sessions
  - Adversary may corrupt the client or sever (learning password information), but this shouldn't compromise past sessions

# PAKE Protocols

- Several constructions, starting in early 90's, providing varying levels of security
- Typical construction uses H(passwd) to mask a DDH key-exchange
  - Due to DDH security, eavesdropping adversary doesn't learn the key
  - Without password, an adversary playing as client/server doesn't learn the key accepted by its honest partner
  - Example: Server stores (v,s) where $v = g^{\pi}$ with $\pi = H(s,pwd)$ client→server: $g^x$ ; server→client: u, $v+g^y$ ; $K = (g^y)^{x+u\pi} = g^{xy} \cdot v^{uy} = g^{xy} \cdot g^{u\pi y}$. Key = H(K).
    - Without adaptively chosen u, an attacker knowing v only can succeed by sending $g^x/v$ in the first step

# PAKE Protocols

- Protocols currently used in practice are proven secure in the random oracle model (under multiple security definitions)
  - Standard model protocols are known
- Need more comprehensive definitions to address concerns of composition: e.g., when multiple (related) passwords are used with multiple servers
- Universally Composable security (REAL/IDEAL security definition)
  - In the IDEAL world, a trusted party comparing passwords and allocating random keys. Passwords come from the environment
- But not realisable without a setup (e.g., random oracle, or common random string)