Crypto with Passwords

Lecture 22

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, a session key should be set up.
  - Also, often Mutual Authentication (if server/client can't/doesn't want to use certificates alone 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.
  - Even 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: If no certificates, client may not a priori know if the server is genuine
- Requires the key to look random to the adversary
  - Unless the adversary guesses the password and impersonates the client
    - Rate/number of attempts limited so that online dictionary attack has a small success probability
- Naïve (non-)solution (in the random oracle model)
  - Client sends passwd to server, server checks if H(passwd) matches a stored value, and then they both use this as key

Key from Password

- Naïve (non-)solution: Server stores Key = H(passwd)
- If the server is compromised, an attacker can launch an offline dictionary attack to recover many passwords
    - Attacker may possess a "Rainbow Table" — precomputed hashes of a dictionary — and can quickly recover almost all the stored passwords
- Key is not pseudorandom (even if server not compromised) since an offline adversary can enumerate a "short" list of possible keys
- Typical solutions
    - **Salting** prevents Rainbow Table attacks: Store H(passwd,salt) where salt is a long random string (sent to the client)
    - Key should be used only for setting up an authenticated channel (i.e., ensure forward secrecy)
    - 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 offline 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".

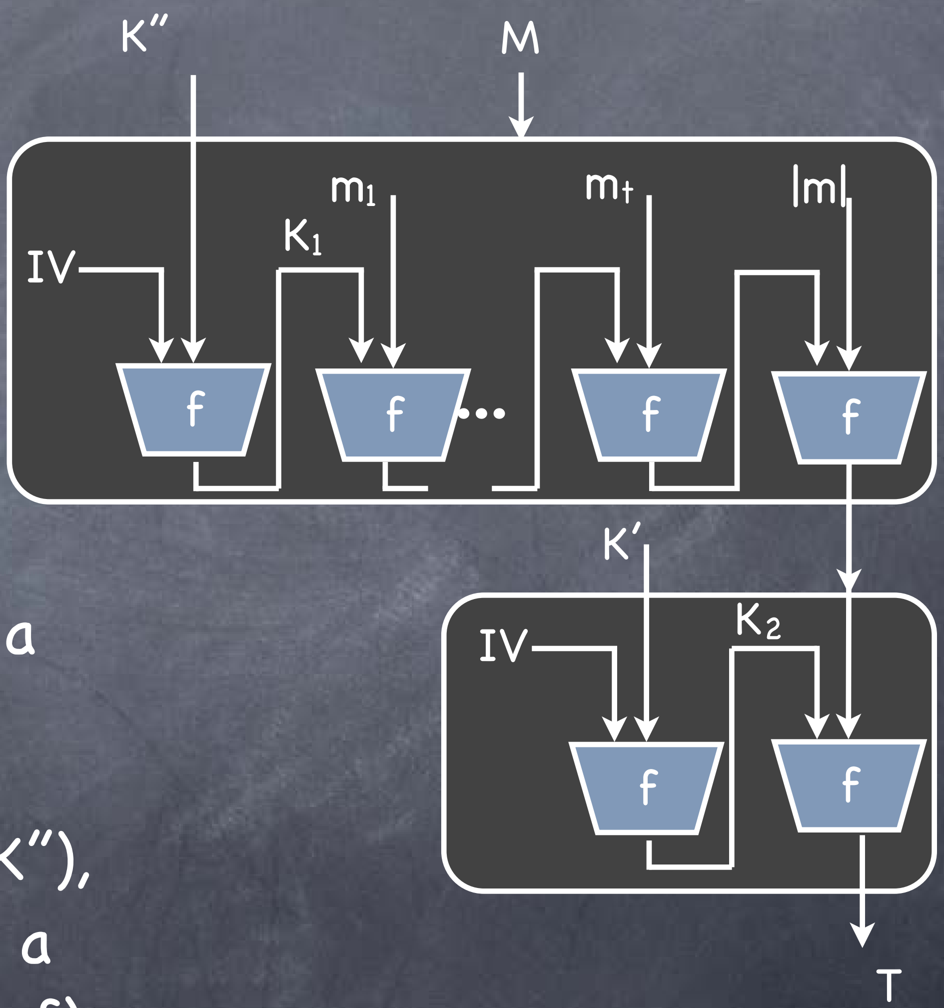
In standards in this area, H is in fact called a "PRF" rather than hash

- 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, 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 not too expensive
  - Solution (on going research): Memory Hard Functions
    - Fast memory is still very expensive
    - So try to make the function require 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 over the authenticated channel 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 that use the same password (MITM attacks)
  - 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 server (and may learn the password), 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 given (v,s) to store, where $v = g^{\pi}$, $\pi = H(s,pwd)$. client$\rightarrow$server: g^x ; server$\rightarrow$client: s, $v+g^y$ (i.e., v as a mask); $K = K_{clnt} = (g^y)^{x+\pi} = K_{srvr} = g^{xy} \cdot v^y$. Key = H(K).
    - Problem: attack by knowing just v. E.g., send g^x/v in the first step), so that $K_{srvr} = (g^x/v)^y.v^y = (g^y)^x$

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    - Fix: Server picks a random u, to force the client to know π (and hence pwd)

PAKE Protocols

- Protocols currently used in practice are proven secure in the random oracle model under various security definitions. Standard model protocols are also known.
- More comprehensive definitions address composition issues: 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 provided by parties, and if equal, allocating them random keys. Note: Even in IDEAL, security depends on passwords.
  - Needs a setup (e.g., random oracle, or common random string)
    - E.g., OPAQUE, in the random oracle model, under the "One-more Diffie-Hellman assumption". Avoids revealing salt by using "Oblivious PRF"