An Intro to Network Crypto

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Crypto outline

- overview
- symmetric crypto (DES ... encryption)
- hash/MAC/message digest algorithms
- asymmetric crypto (public key technology)
- DH - how to start a secure connection
- KDC - a little bit on shared secret servers
- signatures - authentication with asymmetric keys
- certificates - signed public keys
- a little bit on authentication

overview

- there are MANY crypto algorithms and MANY academic network secure protocols
- how they are used in network protocols is another matter
- traditional IETF RFC said under security considerations (at end of doc)
  - "not considered here" (another F. Flub)
- new IETF POV: **must consider here**

symmetric encryption

- both sides know OUT OF BAND shared secret (password, bit string)
- encrypt(key, plaintext) -> cybercrud(encrypted)
- decrypt(key, cybercrud) -> plaintext
- encode/decode use same key (symmetric)
  - shared secret on both sides
- algorithms include: DES, 3DES, IDEA(128), BLOWFISH, SKIPJACK, new AES
- ssh uses 128 bit keyed IDEA
- DES key 56 bits - 0xdeadbeefdeadbeef

DES-CBC

- Cipher Block Chaining Mode
- DES processes one 64 bit block of data at a time (key is 64 bits (8 bits not important))
- CBC is used so that e.g., two 64 bit blocks in a row that are the same, do NOT produce two 64 encrypted blocks that are the same
- C(n) = Ek [C(n-1) xor Plaintext(n)]
- requires known IV or initialization vector

pros/cons

- pros
  - faster than asymmetric
- cons
  - shared secrets do not scale in general to many users
    - more people know secret, less of a secret
  - secrets hard to distribute
  - export laws have blocked encryption software
  - DES key length too short?! (RSA challenge)
    - 2-3 bits a year used up by Moore's law

mention briefcase man Jim

- how do get the shared secret from spot A to B
- no we do not publish it on the web
- "out of band"
- this is a GENERAL problem in secret distribution
  - is is N**2 for symmetric keys, but can be made linear with a server Or with public-key crypto and a server
- in general the need for briefcase man is always there else you are susceptible to a MITM attack

challenge-response with DES

- assume client/server & shared secret

client: server:

------------ send ID (bob) -->

<---- send random challenge X

compute E = f(X, DES key)

------ send E to server -->

decode(E, key)

== X

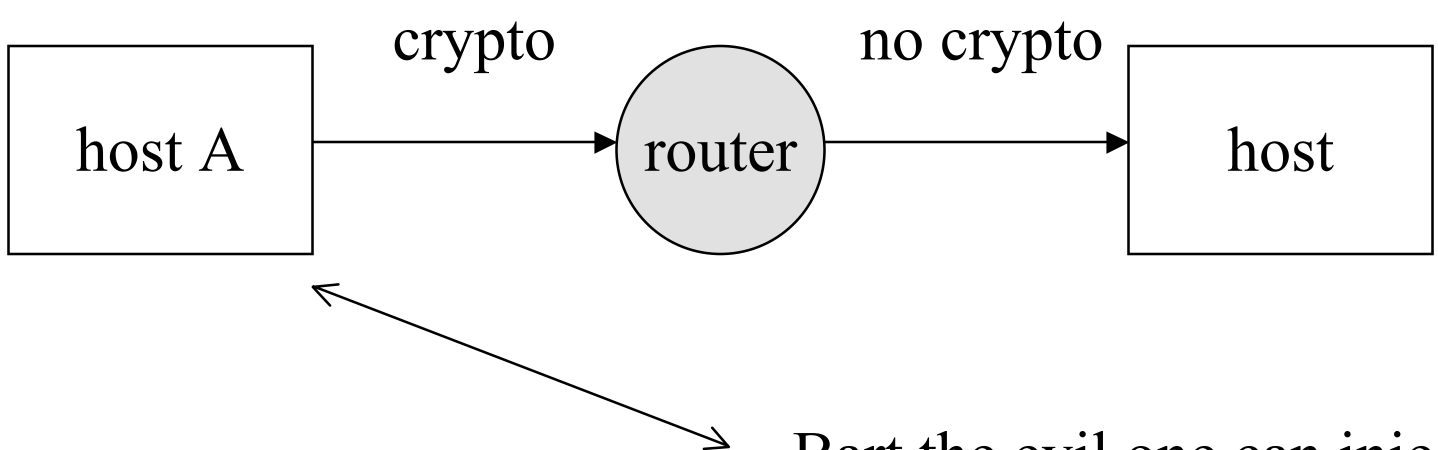
- authentication mechanism (shared secret)

cryptanalysis means what?

- decoding the cybercrud or finding weaknesses in algorithms
- hardest if you don’t know any plaintext
- easier if you know some: known plaintext attack
- easiest if you can suggest the plaintext: proposed plaintext attack
- point: end-end crypto is more secure, why?

why so?

e.g., we have crypto (like IPSEC) between a host and a border router, but not to the server.



Bart the evil one can inject data to host A and see how it is encrypted. ...

media digest algorithms aka

- hash functions OR
- one-way functions OR
- message authentication codes (if used with a shared-secret key)
- e.g., MD5, SHA, HMAC-MD5, HMAC-SHA
- MD5 - RFC 1321 (Ron Rivest)
- Secure Hash Alg. - NIST, FIPS PUB 180-1

media digest functions

- take a message, and produce a non-reproducible bit string (hash or media digest for a file)
  - MD(msg) -> bit string (128 bits with MD5)
- MD(msg, shared secret)-> authenticator
- may be used for password mechanisms
  - longer strings better, FreeBSD 128 byte passwd length
- used with signatures for efficiency reasons
  - MD algorithm faster than public-key
  - we hash the msg, then sign it

examples of MD functions

- download X and MD
  - compare X to MD to make sure you didn't have bit rot
  - does this prevent a hacker from changing X?
- virus game1.exe upload to cwsandbox
  - get media digest - may determine they have seen it before
- nasty porno file has MD
  - police agencies have database of MDs
- used in ID system like tripwire
  - file X hasn't changed recently

when we talk about signatures?

- we are vague …
- 1. pattern matching algorithm used to id virus bits in a file or bits on network
  - what are counter-measures on the black side?
- 2. MD signature used to type files
- 3. digital signature - public key crypto used to sign document (actually sign MD)

one time pad with MD algorithm

- a one-time pad is in theory:
  - an inexhaustible set of random bits of which there are 2 copies
  - briefcase man has gotten it from Alice to Bob
  - we take the msg of N bits and take the next N bits from our inexhaustible store and xor them together to encrypt
  - xor again to decrypt
- or we might use it just for secret key generation
  - every time we need a key, we take a phrase from a shared book and hash it with MD5 to make some bits

how about like this?

- Alice and Bob have a shared secret K(ab)
- Alice computes MD(Kab)
- she xors the message with the hash,
- for the next message block she does
- MD(MD(Kab))
- Alice needs an IV too, but never mind
- we also need a message integrity check

examples

- MD5 - media digest 5, 128 bit string (key)
  - used with RSA signatures
- SHA - 160 bits,
  - used with DSS public key crypto scheme
- MD5 has “flaws” - we may need better MD algorithms or different ideas
- whirlpool - new hash (512 bit digest)

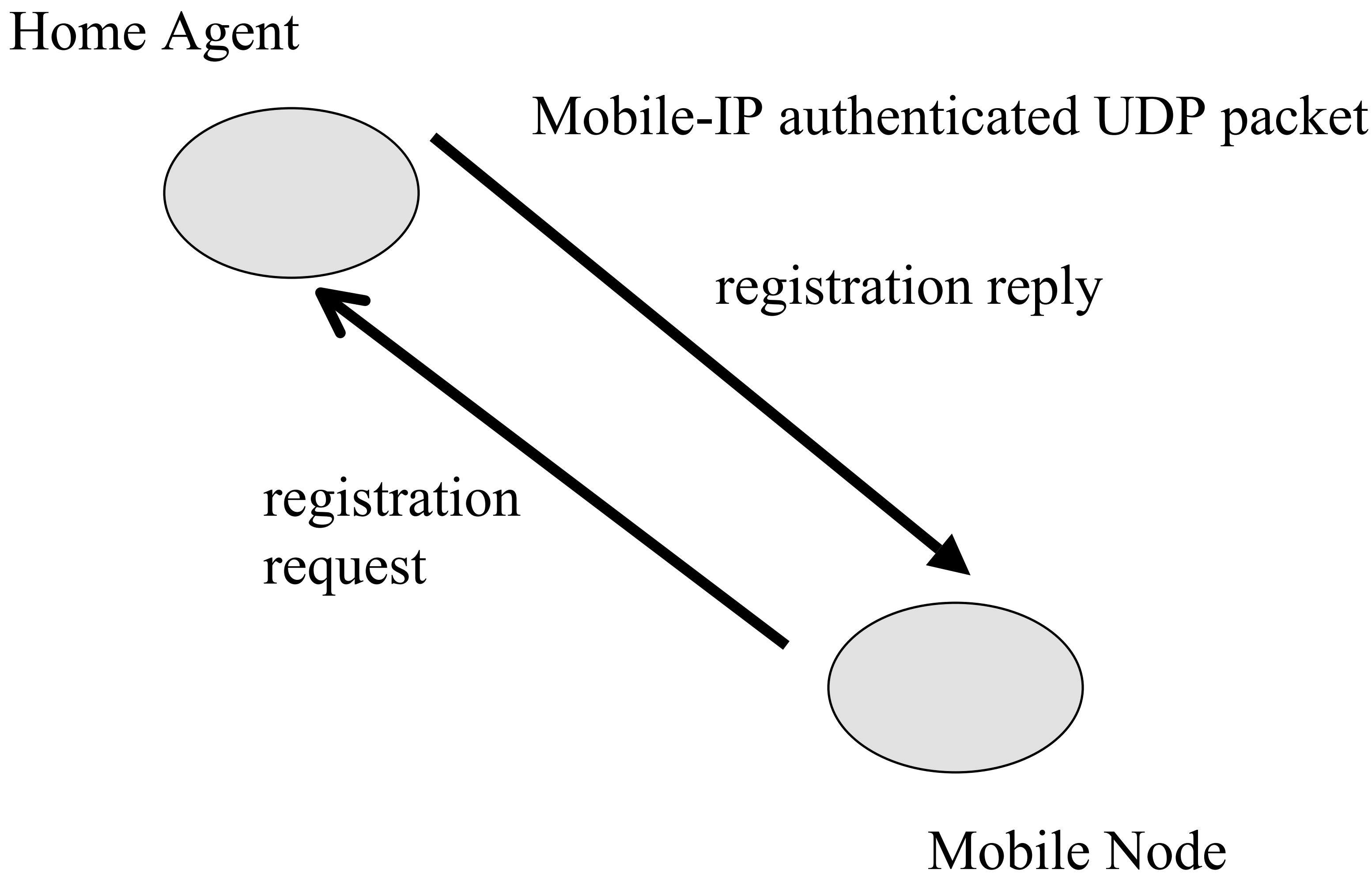
ssdeep - different take on MD algorithm

- fuzzy hashing - Jesse Kornblum
- basic idea: hash can show that f1 and f2 are similar (or totally different)
- ssdeep is a tool he developed
- shadowserver has used it to show similarities in various malwares produced by RBN

HMAC - MD5 (or SHA)

- felt that MD5 and its like needed to be made more secure with attention to MAC function, not media digest function
- also of course, no export control ...
- HMAC - hash message auth. code, RFC2104
- roughly: f[(K xor C1)||f[K xor C2] || msg]
  - essentially two rounds of mac function (f) with cybercrud worked in as appropriate

an example - Mobile-IP



Mobile-IP

- Home Agent keeps key-list of (mobile node IP addresses, per MN 128bit MD5 key)
- MN and HA share 128 bit MD5 shared secret
- compute f(key, msg) and store hash in Mobile-IP registration message
- routing not setup if authentication fails
- note authentication is per IP address as ID

Mobile-IP auth. header encapsulation

IP	UDP	Mobile-IP	128-bit hash

authenticated part

mobile-ip message part (app layer) includes both

1. time bits (nonce)
2. MN/HA ip addresses (ids)

Diffie-Hellman algorithm

- guess who invented it
- public key but doesn't do signatures/encryption
- allows two entities that share two public numbers to arrive at a shared secret that can be used for encryption of further messages
- basis of many "session key" algorithms
- share secure channel and periodically change key (use DH to start, DES for bulk work)

DH might go like this

- Alice/Bob a priori agree on two public numbers:
  - p, a large (>=512 bits) prime
  - g, where g < p
- pre-compute:

Alice	Bob	comment
S(a) = f(random)	S(b) = f(random)	512 bits
T(a) = g**S(a) mod p	T(b) = g**S(b) mod p	

- Alice sends T(a) to Bob; Bob sends T(b) to Alice

cont:

- post-compute of shared secret key material
  - Alice   Bob
  - S(secret) = T(b) ** S(a) mod p

    S(secret) = T(a) ** S(b) mod p
- S(secret) is the shared secret key usable for encryption/authentication and is the same because
- T(b)**S(a) = T(a) ** S(b) as
- T(b) ** S(a) = (g ** S(b))** S(a) = (g **S(a)) ** S(b) = T(a) ** S(b)

cont:

- hard to compute S(a) given only T(a), g, p (hard to compute discrete log)
- may periodically recompute S(secret) based on use of key
  - used for time T then recompute
  - used for data amount Bytes then recompute

questions re DH

- is unauthenticated DH subject to any active attacks?
  - if so, how?
- how can said attacks be fixed with what you know so far?
- why can't Black Bart intercept Alice's first packet and passively compute the shared secret?

paradigm for secure algorithm

- use asymmetric crypto to secure DH messages (e.g., RSA) or even HMAC-MD5
- use DH and handshake to setup session keys and agreement on which crypto algorithms to use for encryption/authentication
- send bulk messages with session-key derived encrypted or authenticated packets
  - using MD5/DES, SHA/IDEA, whatever

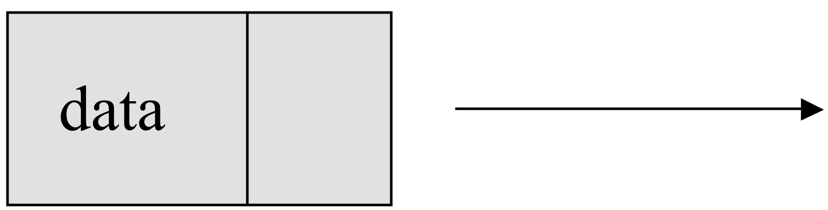
secure protocol paradigm then:

1. handshake

DH(authenticated) gives shared secrets

2. handshake

let’s use encryption X, auth. Y
(e.g., idea/HMAC-SHA)

3. 

bulk per pkt data

encrypted/authenticated data (with security header)

Perfect Forward Secrecy

- PFS defined as:
  - 1. attacker can record entire crypto session
  - 2. attacker can break in and steal keys (public or private)
  - 3. attacker still can't figure out the next session
- would Alice encrypting Bob's email with Bob's public key have this feature?

DH with PFS

- Alice sends Bob: [Alice, g(a) mod p] Alice (sig)
- Bob sends Alice: [Bob, g(b) mod p] Bob
- Alice sends hash(g(ab) mod p)
- Bob sends hash(1, g(ab) mod p)
- Both know the hash, and because
  - 1. DH gives private material based on initial random #
  - 2. hash is 1-way
  - we have unknowable secrets

key-escrow “foilage”

- is something a PFS protocol gives us
- doesn’t matter if big-brother knows all your keys, public/private
- protocol is unbreakable

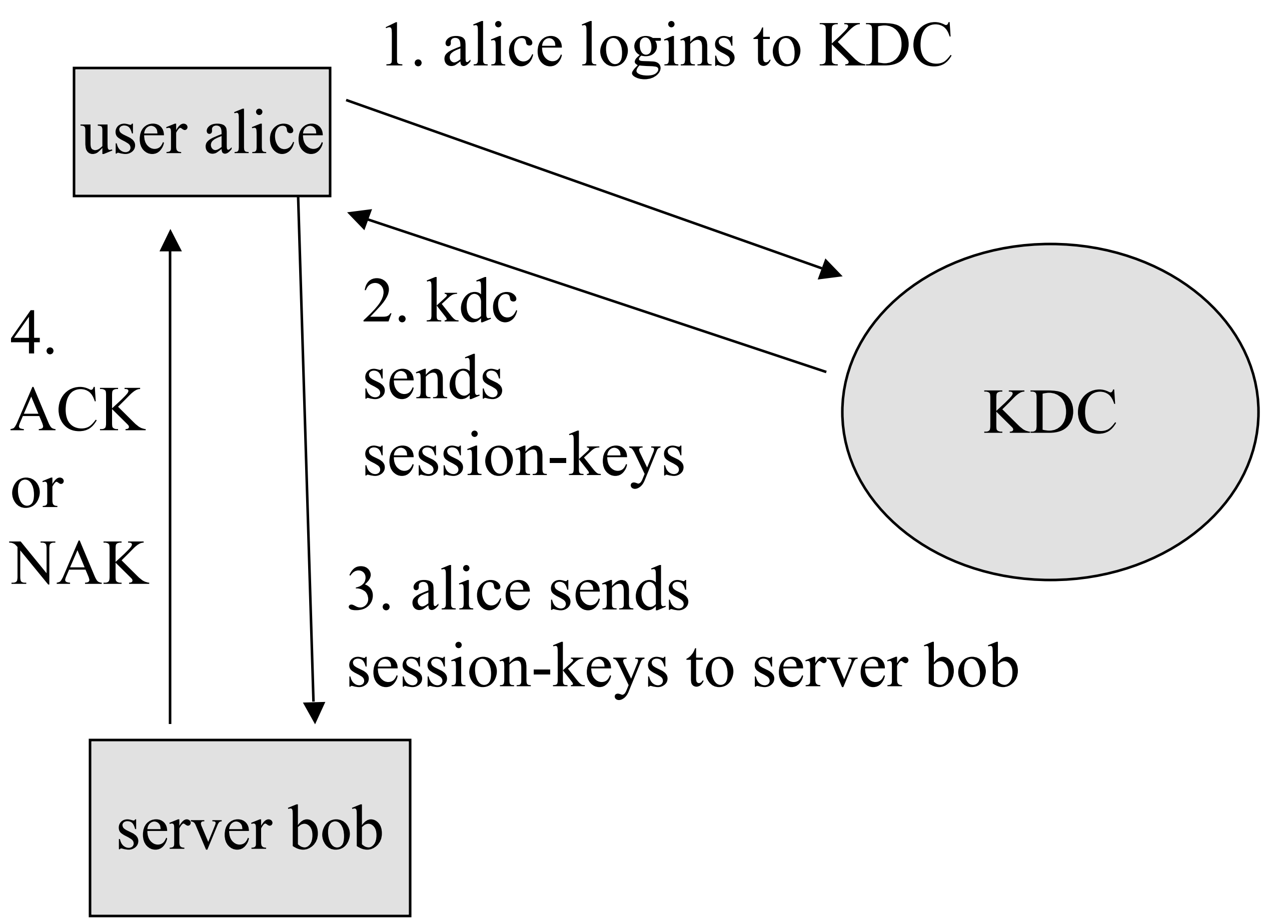
consider this protocol

- generate key via shared-secret and hash
  - and what other properties?
- both sides do sha(shared-secret, other?)
- use that hash as key for privacy
- periodically hash the hash at a certain time
  - time past or bytes sent
- does this give us PFS? if not, what can we do to fix it?

KDC idea

- DH is one-way to establish shared "session keys"
- This is also about the idea of using a protocol to establish keys on both sides
- another old idea is the idea of a symmetric key-server
- you use a key-exchange protocol to get new keys from it
- KDC - key distribution center
  - traditional idea: exchange of symmetric keys
  - for indirect authentication

KDC picture


1. alice logins to KDC
user alice
2. kdc
sends
session-keys
KDC
4.
ACK
or
NAK
3. alice sends
session-keys to server bob
server bob

algorithm underpinnings

- 1. a-priori shared secret between KDC and Alice/Bob
  - 2 master keys
- 2. Alice gets from KDC two session keys
  - 1. one encrypted for Alice with Alice’s master
  - 2. one encrypted for Bob with Bob’s master
  - 3. this is a new Alice/Bob session key
- 3. Alice send’s Bob Bob’s key, and Bob decrypts with Bob’s master key

symmetric session-key system

- think of the new session keys as a 2-way base secret between Bob and Alice
- this can be used for an authentication algorithm between the two now
- this algorithm has problems (MITM and Replay)
  - also single point of failure
  - shared symmetric secrets outside a domain?
- a family of improvements include
  - Needham-Schroder (78)
- Kerberos v4 and v5

asymmetric or public-key crypto

- key generation produces (public, private) key pairs
- can give Public key away, secure private key (somehow ... and hard ...)
- two important services:
  - **signature** - append bit string that proves you signed a message, uses private key (authenticate)
  - **confidentiality** - uses public key (encrypt)

algorithms include:

- RSA - company and algorithm
  - invented by Rivest, Shamir, Adleman
  - key lengths, e.g., 512/1024 or inbetween
  - block size is smaller than key length
  - output will be length of key
- DSS - US govt. competition for RSA
- Diffie - Hellman (older than RSA)
  - doesn't allow signatures/encryption

signatures

- can “sign” a message
- sign(M, **private key**)
  - but actually
  - use Media Digest algorithm to compute hash
  - say MD5 -> 128 bits (hash(M) -> bit string)
  - then run private key over bit string to get signature
  - send (Msg, signature) to receiver
- receiver uses sender public key to verify

confidentiality

- you send me secure email
- obtain my public key SOMEHOW
- encrypt(Msg, public) -> encrypted message
- OK, the message has to be ASCII ...
- I decrypt with my private key
- ? how did you get my public key
- ? what if Joe spoofed me with his public key and you sent him a msg for me

big news (well maybe not)

- public, private keys are cybercrud
- one must make sure public key is somehow truly associated with party X
- and not party Y spoofing party X
- known as "man in the middle" attack if that happens
- various schemes exist for acquiring public keys (ssh/ssl/pgp, including "certificates")

so note four operations

- **sign** (mac hash) with SELF private key
- **verify** (mac hash) with OTHER public key
- **encrypt** with SELF | OTHER public key
- **decrypt** with SELF private key
  - definitely not OTHER, else bad news
- RSA can do all 4. DSS can do sign/verify

Certificate Authorities

- it is presumed that one way to solve the problem of public key distribution
- is to get a signed public key from a trusted 3rd party
- call that node a CA - certificate authority
- nodes need the CA's public key to start with
- can verify "certificate" signed by CA
- certificate = Joe Bob's public key, CA sig

certificate then roughly

- your public key
- your name
- a possible timestamp (it expires at some point)
- signature over all of the above
- you need signer's public key to verify
  - who signed signer's certificate ?

certs, cont.

- certificate can be stored anywhere
  - only CA can generate them
- CA doesn’t have to be accessible
  - but would be if network database of course
- so why don’t we have CAs ?
  - netscape supports certificates and there are a few (verisign)
  - “cross-certification” as opposed to hierarchical cert. may not be possible in some cases

X509 certificate

- version
- serialNumber - with CA's name, ids cert.
- signature - (not the signature), names algorithm used to compute signature
- issuer - name of CA
- validity - how long it lasts
- subject - name of user

X 509 cont.

- subjectPublicKeyInfo - contains algorithm identifier AND public key
- ETC.
- encrypted - (the signature)

certificate formats - > 1 kind

- a few kinds out there at the moment
- X509 (e.g., netscape/web)
  - may be quite large
- RSA may be available in DNS
  - call ‘em DNS certificates
  - sign user name/IP/DNS names
- PGP has its own kind

bottom line:

- a certificate is basically a signed public key
- (public key, name, timestamp, signature)
- what good are they?
- authentication mechanism
- if widely deployed, could replace passwords
- ask how they are stored?
  - if stored on computer, and computer crashes ...?
  - and where is your private key stored too?

principles of authentication

- something you know
  - a password/passphrase/PIN number
  - “abracadabra”
- something you have
  - an object, a VISA card, a “dongle”, a smart card, a physical key
- something you are
  - your fingerprint/retina pattern
- combining these usually improves security
  - Pin # and VISA card

passwords - words while passing thru

- password mechanisms include:
- 1. passwords used as authentication;
  - e.g., with DES on UNIX (prove you know shared-secret)
- 2. authentication done as plaintext over network
  - telnet/ftp/pop/http basic authentication
- 3. advanced password algorithms:
  - one time password or variations on that theme
  - challenge-response with a
  - hw token (counter or timestamp)

passwords

- classic password algorithm:
  – type in a string (blank the screen)
  – convert the string via DES/MD algorithm to a hash
  – compare the hash to a saved hash in a file
  – better: hash a fixed known thing that is somehow unique to user (userid ...)
  – this helps rule out on-line brute force comparison that can match > 1 user in a password file

password problems

- the password is weak
  - force the user to type in a stronger password
- the user writes the password down
  - on a card and then launders it!
  - or puts it on a yellow stickee on his monitor
- dictionary attacks on passwords
- brute-force attacks because password file is easily available
  - exploit gets it or multi-user system makes it easy to get to

password problems cont.

- variation on weakness
  - the password set of characters is too limited
  - too short
    - » uppercase only
    - » a 4-digit PIN number
  - mathematically not terribly random
    - » 256-bit space with ASCII means you lost half your space (7 out of 8 bits)
- a random # is best, expressed in hex

password attacks, cont.

- someone sees you type it in
  - PIN number in a public place ...
  - of course, in that case, there are 2 authentication mechanisms
- if attacker can obtain password file
  - they can take their time guessing to see if they can match Alice/Bob/other users hash
  - off-line attack
  - sometimes on-line attack may be done
  - this is why you get 4 tries and then the bank machine eats your card (or login slows down)

password meta-problems

- user has many passwords
  - different for every computer
  - hard to remember
- which is why security is:
  - usually not helpful in terms of “ease of use”
  - consider the W98 “hit ESC to get around the password”
- not a good system in several variations
  - they make you change your password every 30 days
  - you vary between “hi” and “there”
  - what is your Mother’s Maiden Name?

password meta-problems

- ARE THERE BETTER SCHEMES?
  - yes, but they are uncommon
  - combine > 1 of the basic authentication ideas
  - one-time passwords/hardware tokens
  - why certificates are better, aren’t they?

password case #1 - ssh guessing

- password-based protocols suffer from RANDOM machine-based distributed password guessing attacks.
- ssh/windows login (fileshare)/sql login
  - probably not telnet so much anymore … (still there though)
- what are e.g., ssh counter-measures?
- what are botnets doing about it?

trust relationships are

- **fundamental to distributed secure systems**
- understand the trust relationship 1st
- then design the system
- **risk alleviation** systems may be able to takeover when trust relationships are too hard
  - bank card is stolen - only out $50
- trust relationships consist of
  - us (or us1 plus us2) versus them
- e.g., every computer cannot trust every other computer on the Internet by definition
- interior lines are important

study questions

- given an encryption algorithm like DES, could you design a key establishment protocol that computes a new shared secret between Alice and Bob?
- how do you protect a private-key on-line, on a multi-user o.s.?
- what issues can you think of with storing keys on a computer?
- cryptanalysis is made easier by doing what? where possible.

one more question:

- your bank has just deployed a new wonderful eye-ball scan authentication technique
  – scan eyeball and store in computer file like so:
    » (name, eyeball-scan-bits)
  – user at ATM has eye-ball scanned, compared with bits on computer over network to authenticate
- how many ways can you think of to attack this system?
- what problem previously mentioned does this sound like? is it the same problem?

modest homework request

- get a partner in class
- exchange email addresses
- install GNUPG (pgp in modern guise)
- now send each other a SEKRAT MESSAGE
  - that is signed
  - and encrypted
- be the 1st on the block to become a GNUPG user